Project: Eranet "FutureBioTec":

Project Coordinator: Ingwald Obernberger

Report:

Operational influences of hand-charged wood stoves

Prepared by

Hans Hartmann, Claudia Schön, Peter Turowski (TFZ)

With input from

- Country report Sweden: by Linda S. Bäfver and Christoffer Boman
- Country report Austria: by Joachim Kelz, Thomas Brunner, Ingwald Obernberger
- Country report Germany: by Claudia Schön, Hans Hartmann

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1 State of the art

1.1 General

- The fire box is typically lined with chamotte or fire resistant material.
- Combustion air is supplied as primary air and as secondary air (usually as rinsing air for window cleaning).
- Doors and other non-air supplying openings (e.g. ash drawer) should be fully closable and air-tight to avoid any uncontrolled air supply. This is particularly important if the furnace has a central air supply socket for an external air duct.

1.2 Chimney stoves

- Usual principle: flat furnaces type
- Usual nominal power range: 5 to 12 kW (can be choked to 3 kW). Short burning time of batch, quick availability of heat by radiation and convection.
- Most systems have an iron grate with an ash box underneath. Sometimes there is a vibrating grate actuator (for manual operation) which is also used to open and close the grate for air regulation.
- Air dampers for stoves with grate – Three major solutions are available:
  - Systems with three independently adjustable air inserts for combustion via i) the grate opening, ii) laterally to the fire bottom and iii) as secondary or “purge” air flushed over the window
  - Systems with two independently adjustable inserts for combustion air via i) the grate opening and ii) a multifunctional handle for primary/secondary air insert settings (e.g. as regulator knob or crank)
  - Systems without air adjustment but with automatic grate air closure (non-electronic) and having a fixed primary/secondary air ratio
- Air dampers for stoves without grate – Two major solutions are available:
  - Systems with two independently adjustable inserts for combustion air as i) primary air insert laterally to the fire bottom and ii) secondary or “purge” air flushed over the window
  - Systems with one multifunctional handle for primary/secondary air insert settings (e.g. as regulator crank)

- The usually used fuels are: wood logs of 33 and 25 cm. The share of the 25-cm-logs is increasing due to reduced power demand in modern buildings. Wood briquette use is increasing; brown coal briquettes are still used.

1.3 Tiled stoves

- Usual principle: flat and filling type furnaces, mostly without grate
- Usual nominal power range: 4 to 15 kW. Longer burning time of batch and higher fuel loads are possible if the “filling furnace”-type is used. Slow availability of heat mainly by radiation (during 8 to 12 h after fire extinguishing). But also heat supply by direct radiation (window) and by convection (hot air operation of a tiled stove insert).
- Usual fuel used: wood logs of 25 and 33 cm, sometimes 50 cm.
- Often without grate (flat bottom), deashing with shovel.

2 Stove ignition

A large variation of ignition procedures is described in the user manuals. A clear advice concerning the best ignition aid material is not given. Newspaper (uncoated) is still recommended, but it is obvious, that purpose-designed fire lighters blocks (wax fibre cubes or sticks, wax-soaked wood shaving cylinders or mineral oil cubes) are more favourable due to the longer burning time and better reliability.

In the stove manuals ignition is mostly recommended to be performed from underneath the wood layer. But in some cases the ignition is also suggested from the top of a layer of logs (particularly for tiled stoves with higher charging masses). However, scientific experience provided from Swiss researchers suggests to apply the top ignition method in all cases (Holzenergie Schweiz 2007). Their elaborated ignition leaflet advices to place two layers of logs on the bottom (the larger ones down, smaller ones up) and then to place the so called “ignition module” on the top. The ignition module is a loose composition of four small coniferous wood sticks piled crosswise on each other and having a fire lighter block in the middle. In the recommendation even a vertical orientation of a group of logs with the ignition module on top is suggested for tall fire boxes.

Any measure that speeds up the ignition is useful. Therefore the ignition wood shall be small kindling of usual log length or shorter, preferably soft wood, possibly coniferous, with higher resin content (e.g. the Swiss ignition leaflet suggests fir tree wood). The suggested diameter of kindling is 2 to 5 cm. Also wood shavings or coarse wood chips can be used.

The desired fast ignition is obtained by opening all combustion air dampers entirely or by letting the door stand open in ignition mode briefly. During the course of the combustion of the first batch the primary air supply can be reduced (e.g. after 10 minutes), while the secondary air damper remains open.

It can be concluded, that manufacturer’s recommendations concerning ignition are largely inconsistent or even contradictory, which implies that the phase of ignition was hardly ever been investigated systematically. This may also be due to a lack of a suitable measuring procedure, which is particularly elaborate as the flue gas flow is highly variable in this phase of a log wood stove, and it can hardly be monitored representatively.

3 Stove operation

3.1 Fuels

Suitable fuel lengths are 25, 33 and – for tiled stoves – sometimes 50 cm. Wood briquettes and brown coal briquettes are also used in both stove groups. For chimney stoves a diameter of 7 to 9 cm is sometimes suggested, for tiled stoves up to 10 cm. Sometimes a maximum weight of 1 kg per log is mentioned.

For moisture content the useful range is inconsistent. A moisture content of below 20 % is mostly recommended; sometimes the limitation is 15 %. In some sources ranges of moisture content are mentioned, e.g. 15 to 20 % (Alakangas et. al 2008), or between 14 to 18 %, but it is likely that this has to be interpreted as a range for the maximum moisture content.

However, too low moisture contents (below 9 %) can also be unfavourable in a stove, but this is never mentioned in any of the stove manuals. It was rather shown in research (Hartmann, H. and Turowski, P. 2010), where the rapid ignition of a technically dried fuel batch caused an excessive build-up of combustion gases with are consequently having a lower residence time in the hot combustion zone. On the other side moisture contents above 20 % bear a high risk of increased hydrocarbon emissions.

The combination of fine wood shape and extra dry fuels is reported to be hazardous. This leads to too high burning rate which causes insufficient air supply conditions, especially when full loads of extra dry and fine split logs are combusted (Pettersson et al. 2011).

On the suitability of the specific briquette types the furnace industry provides only little information and also relevant research findings are here hardly available. Only for briquettes from bark a strong warning can be expressed as a result from test stand trials. Their use is usually leading to immensely higher particle and hydrocarbon emissions in

stoves (Ellner-Schuberth et al. 2010). Bark briquettes are applied in chimney stoves for maintaining a longer ignitability in the bed of embers.

As also mentioned in the manufacture’s manuals several fuel types are to be excluded from use in a stove: impregnated, painted or glued wood, wood chipboards, plastics, coloured brochures. Briquettes from non-wood material (for example straw) are also not mentioned among the suitable fuels.

3.2 Fuel charging and stove operation

3.2.1 Chimney stoves

For chimney stoves a typical charging mass is around 1.2 to 2.5 kg (2 to 3 logs), depending on the size of the combustion chamber. Charging is mostly recommended to be done when no more bright flames are visible or “shortly before the flames are out”. Generally the logs shall always be placed on an existing bed of embers. Generally it is recommended to place the logs in the back of the fire box rather than too close to the door in order to allow the purge air to flow freely over the window surface. The feeding shall be done smoothly – probably with the aid of a heat protecting glove – to ensure that the material is not thrown against any chamotte parts which may be damaged.

For the number of wood logs per feeding operation a frequently encountered recommendation is to use 2 logs at a time or to apply a single layer of logs only. Consequently, there is a tendency to increase the number of chargings per hour which may contradict to the operator’s aim of reducing charging efforts. Filling level indications in the combustion chamber were never reported for any of the investigated stoves.

Contradictory information is given for the primary air supply of chimney stoves during combustion. Some sources demand it to be fully closed during combustion; others want it never to be fully closed. A differentiation is sometimes made between two separate primary air streams, one from below the grate (with adjustable grate opening) and the other directed laterally into the fire bed. In this case the air supply through the grate should always be closed after ignition. Exceptions are only suggested for wet fuels, but these fuels should be excluded anyway.

For chimney stoves the recharging of the furnace is usually performed when the primary air dampers are still closed or semi-closed. Directly after recharging the primary air damper is again fully opened and later-on it is closed again, while the secondary air damper remains open. This re-closing of primary air is in some sources to be done 2 minutes after recharging, other sources demand up to 10 minutes time.

It is also stated, that significantly reduced air supply during high combustion leads to pyrolysis causing large quantities of pollutant emissions and low efficiency. An adjustment of the secondary air damper is sometimes recommended to control the heat output,

however, as the charging intervals are desirably short, it is questionable whether this procedure will not rather lead to false operation due to the fact that the demand for frequent re-settings and adjustments are forgotten after recharging. Such differentiated operational instructions are sometimes primarily aiming at achieving favourable type testing results rather than being practical for everyday use.

3.2.2 Slow heat releasing stoves

For the operation of tiled stoves it is recommended to stack the wood cross wise in layers into the fire box. If the fuel is staked loosely it is lighted from the bottom, if packed tightly the lighting of the upper third is recommended. Loose or tight stacking is performed to keep the fuel mass relatively constant while both, soft or hard wood logs are filled to equal heights in the fire box.

For tiled stoves it is usually recommended to close the air intake fully when the char burout begins (only blue flames are visible). This is to conserve the heat for any further ignition. From the viewpoint of combustion quality this recommendation may be questioned. However, the burning time of a batch is usually longer for tiled stoves than for chimney stoves.

If an adjustable grate opening is given, the grate should be closed during normal combustion and not be operated.

3.3 Ash removal

Before re-igniting the ash from the previous operation should be removed. If the furnace has a grate the ash is discharged through the grate into the ash pan (drawer). The removal of ash is a frequent but not an every-day task, depending on the size of the ash pan. Overloading of ash shall be avoided in order to prevent high ash layers from blocking the grate air supply as required for rapid ignition. Safety requirements are to be followed (e.g. disposal of hot ash).

From fireplaces without grate the ash should not be completely removed. A thin layer of ash is recommended to remain in the firebox, to preserve the bottom lining.

4 Maintenance

In the point of maintenance the recommendations are quite uniform and clear. Maintenance shall be done at least once a year in cold condition by removing the ash deposits in the connecting flue gas pipe or on draft baffle plates. Sometimes the manufacturers recommend removing the baffle plates or the connecting pipes for cleaning. Defect

plates shall be replaced. The stove shall be fully cleaned inside and checked for any signs of wear (e.g. sealing material). Chimney sweeping has also to be done regularly.

5 Further equipment

Further equipment for retrofit optimisation is available but it is not widely used. For example the use of a flue gas thermometer can provide interesting information about heat losses due to excessive flue gas temperatures, but such recommendation or advice is usually not provided by the furnace manufacturers.

Automatic electronically controlled air supply units (by air flap adjustment) are available for both chimney stoves and tiled stoves. A market inventory of the systems is given in Table 1. Although a high availability is meanwhile given, the electronic control systems are today still hardly used for chimney stoves. For high-value tiled stoves, however, they have become a significant feature for some manufacturers.

Most tiled and chimney stoves are today released with a central air inlet socket which could allow a retrofit installation of an electronic air control device, given that the respective air flap settings for the furnace type are available by previous adaptation procedure. Thus, the potential for further technical improvements of existing installations is relatively high.

Table 1: Currently available microprocessor controlled air supply systems for stoves (all devices are equipped with display and air regulation flap)

Manufacturer	Application	Principle	Features	Price (€)
BBT Thermotechnik GmbH, Buderus Deutschland	Chimney stoves	Regulation according to flue gas temperature and flow in flue gas pipe	Applied in own stoves only, additional features: e.g. room air ventilation	2000
Brula GmbH	Slow heat releasing stoves	Regulation according to flue gas temperature	Applied in own stoves only	1000
Haas und Sohn Ofentechnik GmbH	Chimney stoves	Regulation according to flue gas temperature	Applied in own stoves only	not available
Kutzner + Weber GmbH	Chimney stoves (unspecific)	Regulation according to flue gas temperature and flow in flue gas pipe	Suitable for all stoves with central air insert socket, extended versions for room air ventilation available	1800
LEDA Werk GmbH & Co.KG Boekhoff & Co	Slow heat releasing stoves	Regulation according to flue gas temperature	Applied in own stoves only	1400
Olsberg Hermann Everken GmbH	Slow heat releasing stoves	Regulation according to flue gas temperature	Applied in own stoves only	1150
Rika Innovative Ofentechnik GmbH	Chimney stoves	Regulation according to flame temperature sensor	Applied in own stoves only	not available
Schmid Feuerungstechnik GmbH & Co. KG	Slow heat releasing stoves	Regulation according to flue gas temperature and flow in flue gas pipe	Applied in own stoves only, extended version includes deactivation of exhaust hood	1500
Ulrich Brunner GmbH	Slow heat releasing stoves	Regulation according to flue gas temperature	Applied in own stoves only, extended version includes deactivation of exhaust hood	900
WGS - Wärmegerätebau Steyr GmbH	Slow heat releasing stoves	Regulation according to flue gas temperature	Applied in own stoves only, extended version includes deactivation of exhaust hood available	1600

Electronic fans for wood stoves are completely uncommon. The use of bleed air flaps to prevent excessive chimney draught in critical stages of batch combustion is sometimes recommended by the chimney manufacturers, but this measure is mostly limited to new chimney installations.

6 References

Alakangas, E. et al. (2008): Efficient and environmentally friendly biomass heating – Firewood production and use in fireplaces and stoves. Manual published by Technical Research Centre of Finland (VTT), VTT-R-11187-08. Download: www.biohousing.eu.com/stoveheating.

Pettersson, E., Boman, C., Westerholm, R., Boström, D., and Nordin, A. (2011): Stove performance and emission characteristics in residential wood log and pellet combustion-Part 2: Wood stove. Energy and Fuels 25(1):315-323.

Ellner-Schuberth, F.; Hartmann, H.; Turowski, P.; Roßmann, P. (2010): Partikelemissionen aus Kleinfeuerungen für Holz und Ansätze für Minderungsmaßnahmen. Berichte aus dem TFZ, Nr. 22, Technologie- und Förderzentrum (TFZ), Selbstverlag, Straubing, 134 p. Download: www.tfz.bayern.de

Hartmann, H.; Turowski, P. (2010): Fuel moisture influences in log wood combustion. In: Proceedings 18th European Biomass Conference & Exhibition - From Research to Industry and Markets. Lyon, France, 03-07 May 2010. ETA Renewable Energies (Eds.), Florence, Italy, pp. 1306-1311

Holzenergie Schweiz (2007): Richtig Anfeuern - Holzfeuerungen mit oberem Abbrand. Merkblatt der Holzenergie Schweiz, Neugasse 6, 8005 Zürich/Switzerland. Publication-No. 315

Annex 1

Country report from Sweden

Evaluation of emission reduction strategies for stoves: *Operational influences*

Example of a typical Swedish Chimney stove in two versions

Contura 590

Contura 590T

Dimensions

	C590	C590T
- Height (mm)	1540	1540
- Width (mm)	490	536
- Depth (mm)	440	458
- Weight (kg)	130	230 (which of 120kg is soapstone)

Technical data

	C590
- Effect (kW)	3-7
- Nominal effect (kW)	5
- Efficiency	80 %

SP Technical Research Institute of Sweden

Ignition of a chimney stove

All examples that follow are for the chimney stove Contura 590 and all information is found in “Installation instruction Contura 590 & 590T” and ”Lighting and Maintenance Instructions for Contura 500”, see reference page.

Recommended stove adjustment:

The connecting sleeve coupling on the chimney has an outer diameter of 150 mm and the chimney requires a draft of a minimum of – 12 Pa. The recommended chimney length is 3.5 m with a cross section of 150-200 cm^3.

The connecting sleeve coupling of the air inlet has an outer diameter of 64 mm. The chimney stove requires approximately 25 m^3 air/h.

Ignition wood recommended (type, shape, size, amount)

All kinds of wood, such as wood of birch, beech, oak, elm, ash, conifers and fruit trees can be used in the stove.

Ignition wood: Kindling
Length: 25 - 33 cm
Diameter: 2 - 5 cm
Mass at ignition: 2.2 kg (about 8 to 10 kindling bits)

Ignition procedure (assembling of wood, ignition aid, air adjustment)

1. Open the slider fully to the combustion air.
2. Put newspaper or fire lighters, and approximately 2.2 kg fine kindling in the middle of the stove. The wood stacked underlying back and forth.
3. Light the fire.
4. The door is in its ignition mode, i.e. the lower tiedown hook must be hooked on the turning key. After about 5-10 minutes close door completely.
5. Put 2-3 sticks of wood with a combined weight of 1.7-2.5 kg before the flame goes out. After about 5 minutes when firewood has ignited properly, reduce the combustion air.

Additional information

It is important that the wood quickly catches fire. Fast ignition is obtained by opening the combustion air damper entirely or to let the door stand in ignition mode briefly. Pyrolysis, i.e. significantly reduced air supply, provides only mild combustion causing large quantities of emissions and low efficiency, and at worst it may cause rapid ignition of gas with damage to the stove as a result.

On Contura's homepage, an instruction video in Swedish is available complementing the lightning instructions. (http://www.contura.se/accessoarer/ved_och_eld.asp)

Operation of a chimney stove

Recommended fuel types, size and moisture content

All kinds of wood, such as wood of birch, beech, oak, elm, ash, conifers and fruit trees can be used in the stove. The wood should have a moisture content lower than 20 %.

Not suitable as fuel (warning from manufacturer): Pressure impregnated, painted, or glued wood, wood chipboards, plastics, coloured brochures.

Wood: Split wood logs (see types above)
Length: 25 – 33 cm
Diameter: 7- 9 cm
Normal mass: 1.7 kg/h

Minimum mass: 1.5kg/h

Maximum mass: 2.5kg/h (maximum three pieces per load)

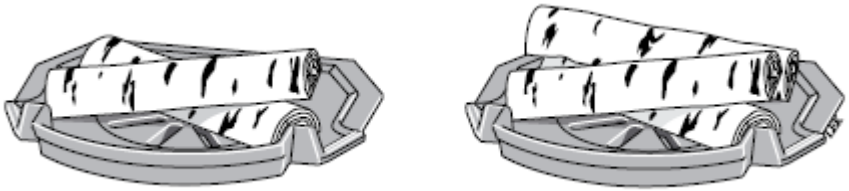
The fire should not be too large. Large fires are wasteful and also provides high flue gas temperatures that may damage the stove and chimney. The recommended loads are for birch or other hardwood with about 18% moisture content. If firing with the same fuel amount as above using softwood could achieve significantly higher furnace temperatures. Firing at maximum load for longer periods shortens life span. Exceeding the maximum allowable amount causes damage to stove-parts and the warranty does not apply.

Nota bene: No available information about suitability for briquettes

Recommended fuel reloading

When the fire has burned down to a glow, it is time to put on wood.

1. Open the handle to the door and let the pressure in the combustion chamber be balanced for a few seconds before opening the door completely.
2. Apply 2-3 logs of wood to a combined weight of about 1.5-2.5 kg. Place a log of wood diagonally and one or two logs parallel to the spine, as illustrated below. Then close the door.
3. Combustion air damper must be fully open during 2-3 minutes until the firewood has become black and burns properly. If you then want a slower combustion, the air supply can be reduced.



Recommended air and chimney flap adjustments

When reloading the stove the combustion air damper should be left wide open until the wood is black and fully ignited (approx. 2-3 minutes). For a nominal effect of 5 kW the air damper should then be 40 % open and for 3-4 kW the air damper can be 20 % opened. If the latter is chosen the air damper should be open for 3-5 minutes after reloading wood.

Ash handling recommendation

In order to quickly get a good glow bed, there should always be a thin layer of ash and char pieces in the stove.

When the ashes in the ash box are to be emptied, ensure that there is no glow left. The ashes should be stored in a non-combustible container with a lid for at least a week before being disposed.

To avoid soot forming, the following is recommended:

- Make sure to keep the recommended moisture content
- Make sure to keep up the temperature in the stove
- Make sure to keep the combustion air damper open for a few minutes after ignition and reloading of fuel.

Example of a typical Swedish Slow heat releasing stove

Cronprinsen Allmoge 500-series

Dimensions (for Allmoge 520)

- Height (mm)	2350
- Diameter (mm)	870
- Weight (kg)	1300

Technical data

- Nominal effect (kW)	2-4
- Efficiency	87 %

Ignition of a chimney stove

All examples that follow are for the heat releasing stove Allmoge 500-series and all information is found in “Installation instruction Cronprinsen 500” and ”Lighting and Maintenance Instructions for Cronprinsen 100, 200, 500”, see reference page.

Recommended stove adjustment:

The connecting sleeve coupling on the chimney has an outer diameter of 150 mm and the chimney requires a draft of a minimum of – 12 Pa. The recommended chimney length is 3.5 m with a cross section of 150-200 cm^3. The connecting sleeve coupling of the air inlet has an outer diameter of 64 mm.

The stove must “rest” for a minimum of a week after being installed before getting used.

Ignition wood recommended (type, shape, size, amount)

All kinds of wood, such as wood of birch, beech, oak, elm, ash, conifers and fruit trees can be used in the stove.

Ignition wood: Kindling
Length: 25 - 33 cm
Diameter: 2 - 5 cm
Mass at ignition: 2.5 kg (about 10 to 12 kindling bits)

Ignition procedure (assembling of wood, ignition aid, air adjustment)

1. Open combustion air supply fully.
2. Put newspaper or fire lighters, and approximately 2.5 kg fine kindling in the middle of the stove. The wood stacked underlying back and forth.
3. Light the fire. Keep the door open, approximately 10 mm.
4. After about 10-15 minutes close door completely.
5. Put in 2-3 logs of wood with a combined weight of 2.5 kg before the flame goes out. After about 5 minutes when firewood has ignited properly, reduce the combustion air.

Slide valve positions

Additional information

It is important that the wood quickly catches fire. Fast ignition is obtained by opening the combustion air damper entirely or to let the door stand in ignition mode briefly. Pyrolysis, i.e. significantly reduced air supply, provides only mild combustion causing large quantities of emissions and low efficiency and at worst can cause rapid ignition of gas damage to the stove as a result. It is also important to keep the slide valve open until all glow has burned out.

Operation of a slow heat releasing stove

Recommended fuel types, size and moisture content

All kinds of wood, such as wood of birch, beech, oak, elm, ash, conifers and fruit trees can be used in the stove. The wood should have a moisture content lower than 20 %.

Not suitable as fuel (warning from manufacturer): Pressure impregnated, painted, or glued wood, wood chipboards, plastics, coloured brochures.

Wood: Split wood (see types above)
Length: 25 – 33 cm
Diameter: 7- 9 cm
Normal mass: 2.0 kg/h

Minimum mass: 3.0 kg/h

Maximum mass: 3.0 kg/h (maximum three pieces per load)

Maximum total mass: 12 kg/combustion (followed by 9-12 hours of cooling)

Maximum mass per day (24h): 24 kg divided in two 12 kg-combustions

A recommendation is to not exceed 65 C as surface temperature

It is recommended that the stove is used regularly. Firing at maximum load for longer periods shortens life span. Exceeding the maximum allowable amount cause damage to stove-parts and the warranty does not apply.

Nota bene: No available information about suitability for briquettes

Recommended fuel reloading and chimney flap adjustments

Just before the fuel is consumed and the fire has died it is time to reload the stove.

1. Open the hatch and let the pressure balance for a few seconds before opening completely.
2. Use 2-3 logs of wood (2-2.5 kg). Place the logs with a bit of space between them. Close the hatch.
3. Let the combustion slide valve be open for approximately 2-3 minutes until the wood logs are black and have caught fire. After this the air supply can be decreased if a slower combustion is wanted. Make sure the fire always burns with clear light-coloured flames.
4. Repeat the loading of wood two times (do not exceed the maximum total weight of 9 kg/combustion). Let the stove cool down (release the accumulated heat) for 9-12 h before starting a new combustion cycle.
5. When the glow has died the air supply can be closed. This will avoid heat loss through the chimney during cooling.

Ash handling recommendation

When the ashes in the ash box are to be emptied, ensure that there is no glow left. The ashes should be stored in a non-combustible container with a lid for at least a week before being disposed.

To avoid soot forming, the following is recommended:

- Make sure to keep the recommended moisture content
- Make sure to keep up the temperature in the stove
- Make sure to keep the combustion slide valve open for a few minutes after ignition and reloading of fuel.

Features or component parts to increase performance

Thermometers for exhaust temperatures (are they recommended?): No available information

Filling level indications in furnaces: Instructions on fuel amount in Ignition and Maintenance guide. Important to avoid high temperatures and not decrease stove lifetime.

Electronic status information (recharging signals?): No available information

Automatic (retrofit) air control systems (type, description, price, features): No available information

Electrical fan in chimney or furnace: No available information

Secondary heating chamber: Yes, normal for modern stoves.

Which chimneys are recommended? (materials, dimensions, etc.): For the stove used as an example above the recommended chimney length is 3.5 m with a cross section of 150-200 cm^3. The chimney requires a draft of a minimum of – 12 Pa and have to be dimensioned for a flue gas temperature of 350 C. No information about material is mentioned.

Research findings: Chimney stoves

Ignition and operation of a chimney stove:

- Impact of different ignition strategies: *No available research*
- Fuel type differences: *Somewhat higher emissions of CO, TOC, and PAH when burning conifer wood compared to birch wood **
- Performance with wood briquettes compared to wood logs *No available research*
- Wood log size and shape effects: *Too high burning rate caused insufficient air*
- Fuel moisture impacts: *supply conditions when full loads of extra dry and fine splitted logs were combusted. **

- Fuel loading differences
- Impacts of frequency of recharging
- Impacts concerning recharging mode (e.g. position/orientation of log, distance)
- Performance with automatic air control

No available research

* *Boman, C., Nordin, A., Öhman, M., Boström, D., Westerholm, R. Emissions from small-scale combustion of biomass fuels - extensive quantification and characterization, ISSN 1653-0551 ETPC Report 05-01, Umeå, February 2005*

Research findings: **Slow heat releasing stoves**

Ignition and operation of a slow heat releasing stove:

- Impact of different ignition strategies
- Fuel type differences
- Performance with wood briquettes compared to wood logs
- Wood log size and shape effects
- Fuel moisture impacts (please indicate if moisture is given as wet or dry basis!)
- Fuel loading differences
- Impacts of frequency of recharging
- Impacts concerning recharging mode (e.g. position/orientation of log, distance)
- Performance with automatic air control
- Other relevant research issues

No available research within these areas

References/Publications

“Installation instruction Contura 590 & 590T”
http://www.contura.se/modeller/pdf/iav_c590_se.pdf

”Lighting and Maintenance Instructions for Contura 500”
http://www.contura.se/modeller/pdf/BAV%20C500.pdf

“Installation instruction Cronprinsen 500”
http://www.cronspisen.eu/se/pdf/IAV_Cronspisen_500_SE.pdf

”Lighting and Maintenance Instructions for Cronprinsen 100, 200, 500”
http://www.cronspisen.eu/se/pdf/BAV_Cronspisen_SE.pdf

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Annex 2

Country report from Austria

Evaluation of emission reduction strategies for stoves: *Operational influences*

Country report - Austria

Prepared by: Joachim Kelz, Thomas Brunner, Ingwald Obernberger

Date: August 2010

Content

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  - Tiled stoves
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  - RIKA Ofentechnik GmbH
  - HAAS & SOHN Ofentechnik GmbH
  - AUSTROFLAMM GmbH
- Innovative components
- Research activities
- Classification, performance and limitations of individual furnaces for wood
- Summary/Conclusions
- References/Publications

General experience and recommendations:
Austrian market
Chimney stoves & slow heat releasing stoves

Three market-leading manufacturer s of chimney stoves in Austria

- RIKA Innovative Ofentechnik GmbH
- HAAS + SOHN OFENTECHNIK GmbH
- AUSTROFLAMM GmbH

Slow heat releasing stoves (tiled stoves) in Austria

- Austrian tiled stove association - Österreichischer Kachelofenverband
- The Austrian tiled stove association is a non-profit association
- It operates on the one hand on research activities on tiled stoves and on the other hand on public information.
- The membership with the federation is voluntary, whereby both the stove fitter (approx. 600 stove fitter companies) and the supporting industry are represented.
- Member of VEUKO[1] and intensive contact to the Masonry Heater Association (MHA)

[1] European platform for information and consulting of the European Associations of the tiled stove builder's/stove-fitter's trade.

General experience and recommendations:
Chimney stoves
General information

State-of-the-art

- Release of useful heat by radiation and/or convection to surroundings
- Firebox walls typically lined with chamotte or fire resistant material
- Sometimes removable iron grates are inserted, and an ash box is placed below the grate
- Combustion air is normally supplied as primary and secondary air and is usually controlled by manually driven dampers
- They are not only a heating device, in many cases they are also a design element in modern living rooms

Capacity range: between 5 and 12 kW

Fuels used

- Log wood (25 cm or 33 cm)
- Wood briquettes (sometimes coal briquettes)
- Automatically (pellets) fed systems available since a few years

General experience and recommendations:
Tiled stoves
General information (I)

State-of-the-art

- Constructed of pre-fabricated heavy stone plates or purely of stones
- During combustion the heat generated is stored in the stove and after the fire is extinguished, the heat is released to the surrounding during a considerable period of time (usually about 8 to 12 hours)
- Usually in batch operation and especially suitable for cold climates with slow temperature changes
- They are not only a heating device, in many cases they are also a design element in modern living rooms
- Flat bottom (no grate)
- To be de-ashed with shovels
- No air staging

General experience and recommendations:
Tiled stoves
General information (II)

Capacity range : 4 to 15 kW (depending on the tile surface)

Fuels used

- Log wood (25 cm, 33 cm or 50 cm)
- Wood briquettes (unusual)
- Automatically (pellets) fed systems under development

Types

- Individual units built by tiled stove-fitters
- The stove-fitter calculates the stove size and heat output corresponding to the audited calculation guideline of the Research Center of the Austrian stove-fitters ("Versuchsanstalt der Hafner“).

General experience and recommendations:

Chimney stoves:
RIKA Innovative Ofentechnik GmbH

Photographs of typical chimney stoves in Austria manufactured from RIKA Innovative Ofentechnik GmbH

Esprit

Cult

Alpha II

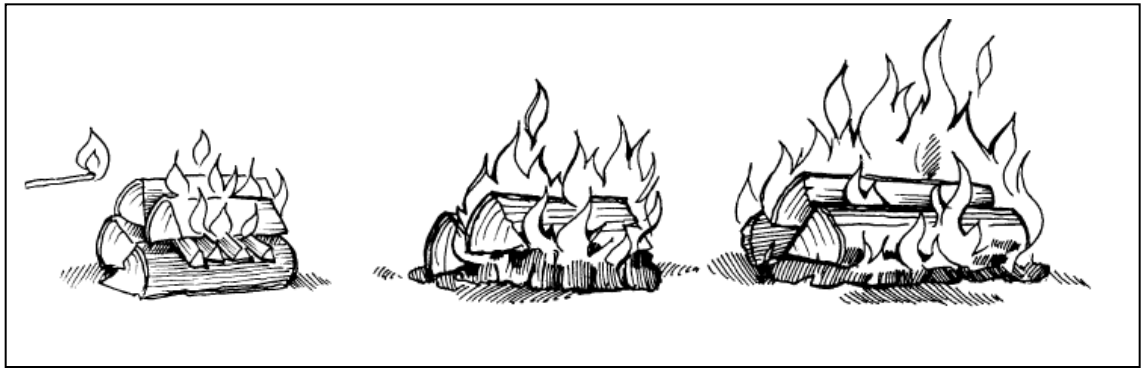
Source: [RIKA, 2010]

Ignition of the chimney stove with a primary air and a secondary air damper (e.g. Esprit, Alpha II) (I)

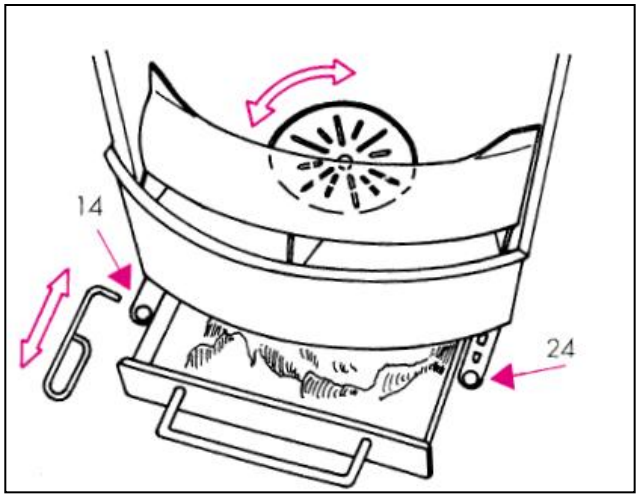
- If the stove and chimney are still cold or if there is atmospheric low pressure, it is recommend to burn some paper initially to heat up the stove and the chimney.
- When heating up, first position 1 kg of wood (2 logs) on the combustion chamber floor. Then place some uncoated paper on top, with approx. 0.8 kg softwood chippings and 1 kg of wood (2 logs) (see picture “lighting” on slide 9).
- Pull the vibrating grate actuator (see picture “primary air” part 14 on slide 9) fully out and open the primary air damper (see picture “primary air” part 24 on slide 9) and the secondary air damper (see picture on slide 10). Now ignite the paper and close the door.
- Wait until the softwood chippings are burning well. Approx. 2 minutes later, close the vibrating grate actuator and the primary air damper. Several minutes later, set the secondary air damper to the middle position and approx. 6 minutes later adjust it to the ideal setting.

Ignition of the chimney stove with a primary air and a secondary air damper (e.g. Esprit, Alpha II) (II)

- When the fire is extinguished, put about 1.5 to 2 kg (depending on the nominal load of the chimney stove) of wood (2 logs) in the firebox. Open the vibrating grate actuator and the primary air damper until the wood is burning well (approx. 2 min.) and close them afterwards. The secondary air damper should remain at the ideal setting.
- For each further fuel layer, proceed in the same way.



Lighting



Primary air

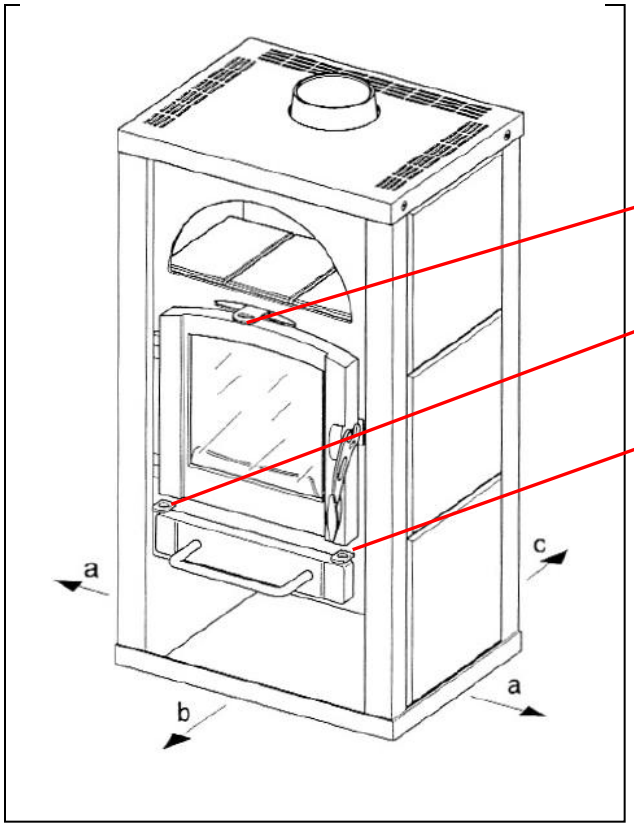
Source: [RIKA, 2010]

General experience and recommendations:

Chimney stoves

RIKA Innovative Ofentechnik GmbH

Ignition of the chimney stove with a primary air and a secondary air damper (e.g. Esprit, Alpha II) (III)



Secondary air damper

Vibrating grate actuator

Primary air damper

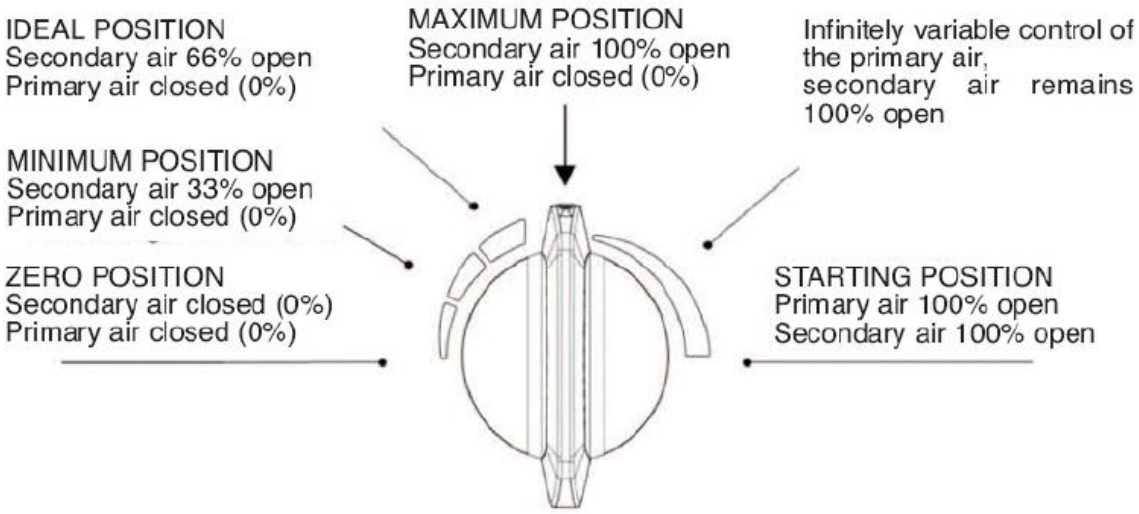
Source: [RIKA, 2010]

Ignition of the chimney stove with a regulator knob (e.g. Cult) (I)

- If the stove and chimney are still cold or if there is atmospheric low pressure, it is recommend to burn some paper initially to heat up the stove and the chimney.
- To light the fire, place uncoated paper at the bottom of the combustion chamber, then 0.5 kg softwood chippings and 1 to 1.5 kg (depending on the nominal load of the chimney stove) wood (3 small logs). Turn the regulator knob to the right to fire lighting setting. Primary and secondary air are completely open (see picture “Regulator knob” on slide 12).
- Now ignite the paper and close the door. Wait until the softwood chippings are burning well. Turn the regulator knob 90° to the left some minutes later. The primary air is now closed and the secondary air is completely open
- Set the regulator knob to the ideal setting some minutes later. Secondary air approx. 66% open, primary air closed.

Ignition of the chimney stove with a regulator knob (e.g. Cult) (II)

- After burn-off, place approx. 1.2 to 1.8 kg (depending on the nominal load of the chimney stove) of wood (2 logs) on the bed of embers. Open the riddle grate and the primary air until the wood burns well.
- Proceed in the same way every time you place more wood on the fire.



Regulator knob

Source: [RIKA, 2010]

Operation of the chimney stove (I)

- The stoves are generally suitable for burning dry and untreated firewood. Deciduous wood is particularly suitable. The stoves also can run with wood briquettes and special stoves (e.g. Alpha II) with brown coal briquettes.
- Moisture content of the fuel should be between 14 and 18 % → 2 - 3 years drying and well ventilated storage.
- Only one layer of fuel must be placed on the existing glowing embers when re-charging.
- Fuel loading: ≈ 1.2 to 2 kg (2 logs, 25 cm or 33 cm long) per layer for rated heating value. For minimum thermal output ≈ 0.6 to 1 kg (2 logs, 25 cm or 33 cm long).
- The ash drawer is to be emptied regularly to prevent excessive loading of the grate.

Operation of the chimney stove (II)

- The moving of the grate causes the ash to be transferred from the combustion chamber to the ash drawer. This gives room for the primary feed air that is required for the start-up phase of a combustion batch.
- The grate should always remain closed. Exception: Wood or briquettes are too moist.
- The grate does not have to be operated during heating.
- Setting for nominal heating
  - Primary air: closed
  - Secondary air: ≈ 66 % open
  - Grate: closed

Maintenance of the chimney stove

- All maintenance and cleaning work is only to be performed on completely cooled stoves. The periods between inspections depend in particular on the quality of used firewood and the frequency of use.
- Remove dust deposits from the convection air openings regularly, using a source of suction.
- Before the start of a new heating season, the appliance should be thoroughly cleaned in order to avoid excess odours during operation.
- Cleaning the flue gas paths (once a year)
  - Remove the flue pipes
  - Brush off/suck out any deposits of soot and dust in the stove and the flue pipes
- Check the seals of the combustion chamber and the ash drawer at the beginning and end of a heating period.

General experience and recommendations:
Chimney stoves
HAAS + SOHN OFENTECHNIK GmbH

Photographs of typical chimney stoves in Austria manufactured from HAAS + SOHN OFENTECHNIK GmbH

Moers

Ystad

Eifel

Source: [Haas + Sohn, 2010]

Ignition of the chimney stove (I)

- Initially place 2 to 3 wood logs (approx. 1.5 to 2.0 kg) on the firebox floor or grate, uncoated paper, cardboard or a lighting cube on top, followed by brushwood, firewood or pieces of briquettes (see picture “lighting” on slide 19).
- All existing air control dampers (primary air I, primary air II and secondary air) must be fully opened (see picture “air dampers” on slide 19). After lighting, close the firebox door.
- Close the primary air damper II after approx. 10 minutes. The secondary air damper remains open.
- Additional fuel should only be placed on the bed of embers (after the flame extinguished). Before opening the firebox door you should fully close all air dampers and put about 1.5 to 2.5 kg (depending on the nominal load of the chimney stove) in the firebox.
- Close the primary air damper I first and after that close the firebox door again.

Ignition of the chimney stove (II)

- Following this, fully open all air dampers immediately to keep the time span to the lighting of the fuel as short as possible. As soon as the fuel is burning well, close the primary air damper II. The secondary air damper remains open.
- For each further layer of fuel, proceed in the same way.

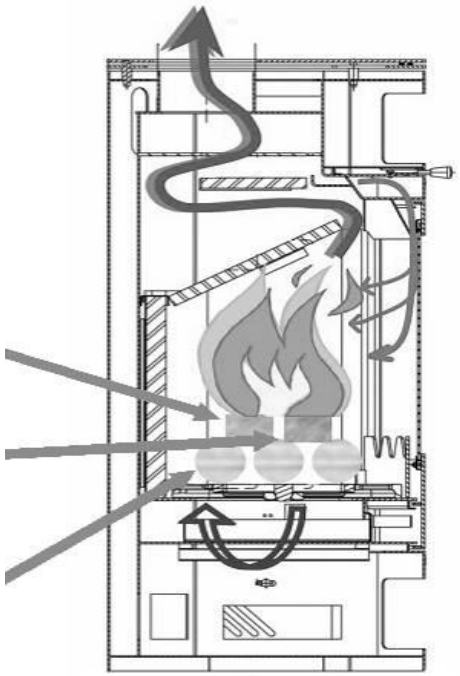
General experience and recommendations:
Chimney stoves
HAAS + SOHN OFENTECHNIK GmbH

Ignition of the chimney stove (III)

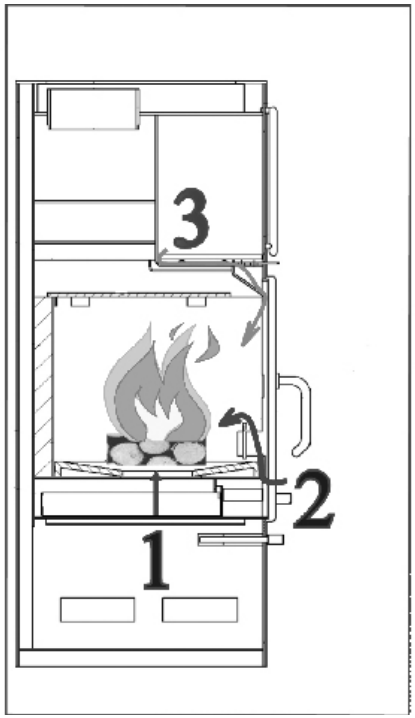
Small wood logs on top

Lighting aid in between

some wood logs at the bottom



lighting



air dampers

1. primary air I: through the grate
2. primary air II: flows onto the fuel in a horizontal direction
3. secondary air / purge air system: pre-heated air from above is the main combustion air for wood

Source: [Haas + Sohn, 2010]

Operation of the chimney stove (I)

- Charging fuel in only one layer.
- The stoves are generally suitable for burning dry, natural wood and can also be fired with wood briquettes according to DIN 51731. Special stoves (e.g. Eifel) can also be fired with brown coal briquettes.
- Additional fuel should only be placed on the bed of embers (after the flame extinguished).
- Preferably use approx. 33 cm long wood logs (filling the firebox width).

Operation of the chimney stove (II)

- Fuel loading:
  - Wood logs ≈ 1.5 to 2.5 kg (2 logs) per layer for rated heating value.
  - Wood briquettes ≈ 1.5 kg (1 briquettes)
  - Brown coal briquettes ≈ 2.0 to 2.5 kg (3 to 4 briquettes)
- After extended combustion, at least once per day, discharge the ash through the grate into the ash pan using a hooked poker and empty the ash pan. This is best done in the morning in a relatively cold state.

Maintenance of the chimney stove

- At least once per year clean and service your stove in cold condition.
- Remove the ash deposits in the flue pipe and the smoke baffle plates or draft baffle plates. Draft baffle plates made of ceramic fibre or vermiculite can be removed for cleaning and reinstalled carefully in the same position after cleaning. For cleaning the flue gas drafts an ash extractor is suitable.
- The chimney must also be regularly cleaned by the chimney sweeper.
- The stove should be checked annually by a specialist.

General experience and recommendations:

Chimney stoves

AUSTROFLAMM GmbH

Photographs of typical chimney stoves in Austria manufactured from AUSTROFLAMM GmbH

Koko

Pallas

Solo

Source: [Austroflamm, 2010]

General experience and recommendations:

Chimney stoves

AUSTROFLAMM GmbH

Ignition of the chimney stove with one air damper for primary air and secondary air (e.g. Koko, Pallas) (I)

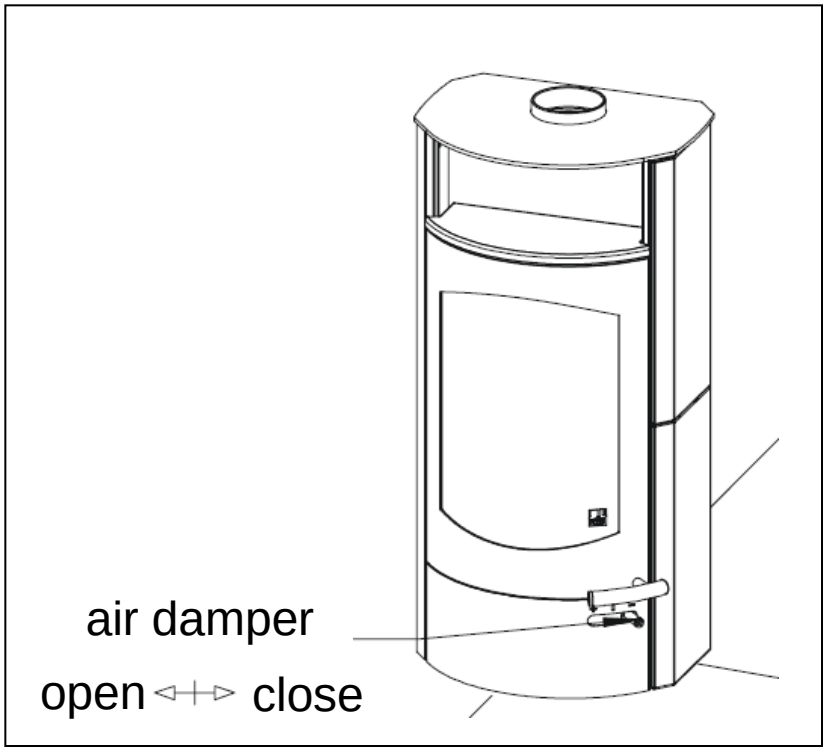
- Fully open the air damper all the way (see picture “air damper” on slide 25). Open the stove door and put 2 to 3 pieces of ignition aid (lighting cube) on the floor of the firebox.
- Put softwood chips onto ignition aid and after that put one or two logs of wood on top of the wood chips. Light the ignition aid and close the firebox door (see picture “lighting” on slide 25).
- As soon as the wood logs are burning well, you can regulate the heating capacity with the air damper.
- When adding wood to the firebox, follow the same procedure as when igniting the fire: Open the air damper, open firebox door, lay wood on the bed of embers, close the firebox door. Wait until the added wood catches fire and is burning. Then regulate the air slider again.

Chimney stoves

AUSTROFLAMM GmbH

Ignition of the chimney stove with one air damper for primary air and secondary air (e.g. Koko, Pallas) (II)

lighting



air damper

Source: [Austroflamm, 2010]

Chimney stoves

AUSTROFLAMM GmbH

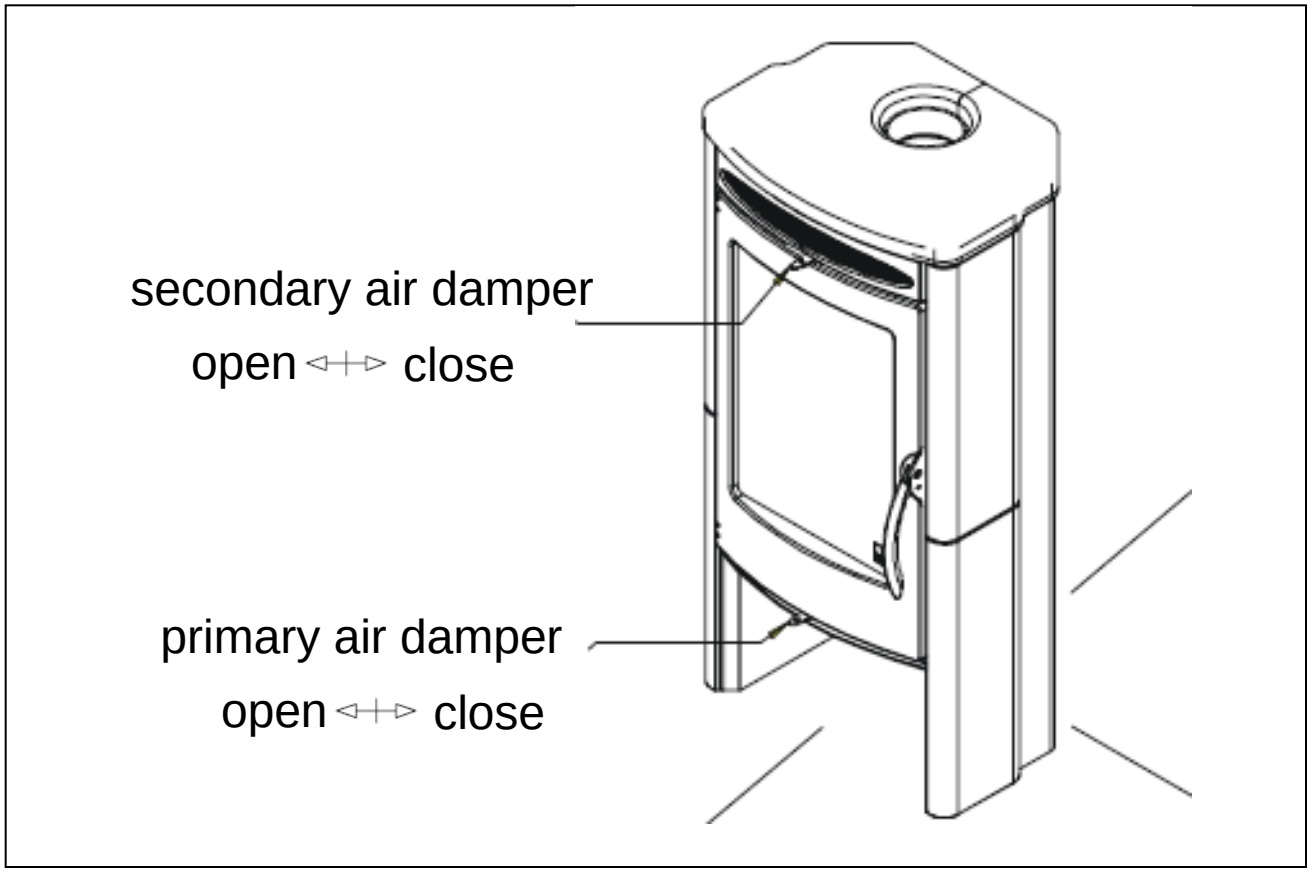
Ignition of the chimney stove with separate air dampers for primary air and secondary air (e.g. Solo) (I)

- Fully open the air dampers for the primary air and secondary air (see pictures on slide 27). Open the stove door and put 2 to 3 pieces of ignition aid (lighting cube) on the floor of the firebox.
- Put softwood chips onto ignition aid and after that put one or two logs of wood on top of the wood chips. Light the ignition aid and close the firebox door.
- As soon as the chips burn well, close the primary air damper. When the wood logs are burning well too, you can regulate the heating capacity with the secondary air damper.
- When adding wood to the firebox, follow the same procedure as when igniting the fire: Open primary and secondary air dampers, open firebox door, lay wood on the bed of embers, close the firebox door. Wait until the added wood catches fire and is burning. Then close the primary air damper. Subsequently regulate the fire with the secondary air damper.

Chimney stoves

AUSTROFLAMM GmbH

Ignition of the chimney stove with separate air dampers for primary air and secondary air (e.g. Solo) (II)



Source: [Austroflamm, 2010]

Operation of the chimney stove (I)

- The stoves are generally suitable for burning dry (relative wood moisture < 15 %), well cured and natural wood (hardwood preferred) and can also be fired with wood briquettes.
- Maximum amount of fuel to be added: 1.3 to 2.5 kg wood (depending on the nominal load of the chimney stove) or 1 kg wood briquettes.

Maintenance of the chimney stove

- The stove, flue outlets and smoke pipes should be cleaned and inspected for deposits every year – if necessary more often, e.g. after the cleaning of the chimney.
- The chimney also has to be cleaned regularly by the chimney sweeper.
- An expert should inspect the stove annually.

General experience and recommendations:

Slow heat releasing stoves

Tiled stove

Photographs of typical tiled stoves in Austria

Source: [ÖKV, 2010]

Source: [ÖKV, 2010]

Source: [Flechl, 2010]

General experience and recommendations:
Slow heat releasing stoves
Tiled stove

Ignition of the tiled stove (I)

To reach an efficient combustion rapidly, stack the wood cross-wise in layers into the combustion chamber. In order to achieve stacks of nearly equal height at using different quantities of fuel, stack the wood adequately loose or dense. To kindle the wood, paper and wood splints or appropriate kindling aids can be used. If the fuel is packed loosely, light it from the bottom, if packed tightly, light the upper third of the stack. Leave the air intake open, after the stove has been successfully heated up.

Additional air through charging door (vertical grate)

1 Even here: pile up wood crosswise

2 After lightning, the vertical grate must be closed, the charging door stays open.

3 If only small flames appear above the glow, the air supply can be shut. You can open the charging door again after 12 hours.

Source: [ÖKV, 2010]

General experience and recommendations:

Slow heat releasing stoves

Tiled stove

Ignition of the tiled stove (II)

Air intake separated from charging door

Stack the wood cross-wise in layers in the combustion chamber and open air intake.

Using few wood, stack logs loosely, light with paper, wood splints or appropriate lighter aids at the lower third .

Using a lot of wood, stack logs densely and light at the upper third.

You can close the charging door, after the stove has been successfully fired up. Air intake stays open.

Depending on the quantity of wood the burning process may last between 30 and 90 minutes.

As soon as only short blue flames (in the case of log wood) or little flames (wood briquettes) can be seen above the glow, you can close the air-intake. Wait at least 12 hours before opening the charging door of your tile stove.

Source: [ÖKV, 2010]

Operation of the tiled stove (I)

- Fuel: tiled stoves can either be fired with log wood or wood briquettes.
  - Only natural, air-dried wood with a maximum moisture content of 20% is suitable fuel for your tiled stove. The right degree of dryness is achieved after two years of well-ventilated covered storage outdoors. All types of wood are suitable, hard and softwood. The thickness of log wood can be up to 10 cm. The choice of length (25, 33 or 50 cm) depends on the dimensions of the combustion chamber.
  - It is recommended to use only wood briquettes according to ÖNORM M 7135. The weight of each individual piece must not exceed 1 kg (if necessary, break up the wood briquettes).
- The stove-fitter calculates the correct stove size and heat output. The calculation corresponds to the audited calculation guideline of the "Versuchsanstalt der Hafner" (Research Center of the Austrian stove-fitters).

Operation of the tiled stove (II)

- The capacity range of tiled stoves is between 4 and 15 kW. To attain maximum output, add the calculated mass of log wood (in the case of wood briquettes about 15 % less mass because they are artificially dried and therefore have higher energy content) in intervals of 8 to 12 hours. The quantity of fuel can also be reduced to half the amount.
- Depending on the quantity of wood, the burning process may last between 30 and 90 minutes. As soon as only short blue flames (in the case of log wood) or little flames (wood briquettes) can be seen above the glow, you can close the air-intake.
- Wait at least 8 to 12 hours (depending on the nominal load and tile surface) before opening the charging door of your tiled stove. Repeat the process, as described above.
- Depending on the frequency of use, you will have to remove the ashes a few times per heating season. A layer of ashes up to 8 cm is acceptable.

Maintenance of the tiled stove

- Tiled stoves require periodic inspection by serviceman to ensure functional efficiency. Even if you seldom use your stove, it is recommendable to have your stove inspected every 5 years at latest.
- Every tiled stove should be maintained at regular intervals. A maintenance contract is recommended.

General experience and recommendations:

Chimney stoves

Features or components to increase performance (I)

- Temperature sensors
  - Temperature sensors are used in special air control systems.
  - Detailed information see later in the presentation.
- Filling level indications
  - They do not exist for using wood logs and wood briquettes
  - It is recommended to use only one layer (2 logs) of fuel.
- Electronic status information (re-charging signals)
  - Electronic status information already exist in special air control systems.
  - Detailed information see later in the presentation.
- Use of soapstone (or something comparably) for storage as much heat as possible to increase the efficiency.

General experience and recommendations:

Chimney stoves

Features or components to increase performance (II)

- Automatic (retrofit) air control systems
  - Rikatronic developed by RIKA
  - intelligent-control (i-control) developed by Haas & Sohn
- Electrical fan in chimney or stove
  - Not applied at the moment.
- Secondary combustion chamber
  - State-of-the-art in Austria
- Recommended chimneys
  - Flue gas tubes
  - Steel sheet at least 2 mm thick
  - 130 to 180 mm in diameter

General experience and recommendations:

Tiled stove

Features or components to increase performance

- Temperature sensors
  - Not applied at the moment.
- Filling level indications
  - They do not exist for using wood logs and wood briquettes
  - In tiled stoves the maximum and minimum weight of the wood logs and wood briquettes is calculated from the stove-fitter.
- Electronic status information (re-charging signals)
  - Not applied at the moment.
- Automatic (retrofit) air control systems
  - Not applied at the moment.
- Electrical fan in chimney or tiled stove
  - Not applied at the moment.

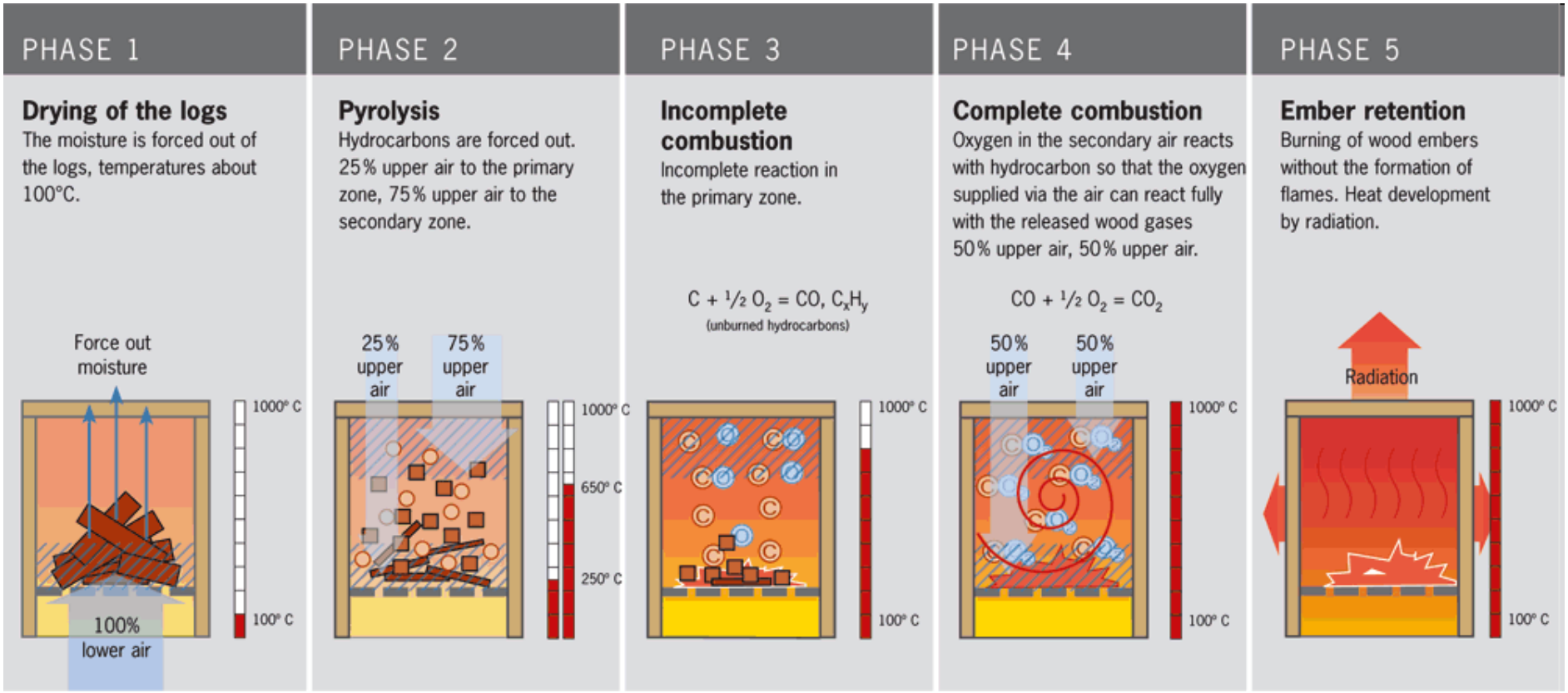
General experience and recommendations:

Innovative components
Rikatronic (I)

- Patented air control system developed by RIKA (see picture on slide 41).
- For each phase of combustion the microprocessor-controlled Rikatronic control supplies the optimum quantity of air for the combustion process.
- This is done in steps by a flame temperature sensor. Meanwhile the RLS system determines the distribution ratio of primary and secondary air/upper and lower air (see picture on slide 40).
- The supply of the primary air (lower air) to the lower zone is controlled by the grate. The secondary air (upper air) helps to improve the combustion process on the one hand and on the other hand acts as purged air for the window.
- At the same time the design of the wood catcher, in conjunction with the respective combustion chamber geometry ensures turbulent air currents and the fire clay promotes high combustion chamber temperatures.
- An acceleration of the reaction of the flue gases released during the pyrolysis phase with the air fed into the combustion chamber is achieved by the temperature-controlled air-flow control.

General experience and recommendations:
Innovative components
Rikatronic (II)

- After the complete combustion phase the control cuts off the airflow automatically and the phase of ember retention begins. In addition the cast door absorbs heat and releases it in the form of delayed radiation into the surrounding space.


PHASE 1
Drying of the logs
The moisture is forced out of the logs, temperatures about 100°C.
Force out moisture
100% lower air
1000° C
100° C
PHASE 2
Pyrolysis
Hydrocarbons are forced out. 25% upper air to the primary zone, 75% upper air to the secondary zone.
25% upper air
75% upper air
1000° C
650° C
250° C
PHASE 3
Incomplete combustion
Incomplete reaction in the primary zone.
C + ½ O2 = CO, CxHy
(unburned hydrocarbons)
1000° C
100° C
PHASE 4
Complete combustion
Oxygen in the secondary air reacts with hydrocarbon so that the oxygen supplied via the air can react fully with the released wood gases 50% upper air, 50% upper air.
CO + ½ O2 = CO2
50% upper air
50% upper air
1000° C
100° C
PHASE 5
Ember retention
Burning of wood embers without the formation of flames. Heat development by radiation.
Radiation
1000° C
100° C

Source: [RIKA, 2010]

General experience and recommendations:

Innovative components
Rikatronic (III)

(1) CONVECTION HEAT

(2) SECONDARY AIR FLOW / UPPER AIR

(3) FIRE CLAY: promotes high combustion chamber temperatures.

(4) LOG GUARD: Directs upper air airflow precisely to the primary zone and promotes turbulent flows.

(5) PRIMARY AIR FLOW / LOWER AIR

(6) RLS AIR DISTRIBUTION SYSTEM

(7) RIKATRONIC: Flame temperature sensor and microprocessor-controlled motor for automatic drive of the RLS air distribution system.

(8) RADIATED HEAT

(9) SOLID HIGH QUALITY CAST DOOR: Keeps the stove airtight even during intensive operation and at high temperatures and prevents incorrect airflow.

Source: [RIKA, 2010]

General experience and recommendations:
Innovative components
Rikatronic (IV)

- 2 types of chimney stoves (Cult plus and Eco plus) with Rikatronic technology are available.
- Ignition and operation of these types of stoves (see pictures on slide 43)
  - To operate the stoves with Rikatronic you have to insert the main plug and operate the main switch on the back of the stove.
  - Open the grate door and on the left and right put two splits of wood longways on the grate floor. On the chipboard lay 3 billets crossways.
  - On the wood logs put more splits crossways. Under this splits place a firelighter on the left-hand side (if necessary uncoated paper can be placed under the splits instead of the firelighter). Open the shaker grate fully, light the firelighter (or the uncoated paper) and close the door.
  - As soon as the temperature exceeds 50°C, the indictor changes to "green„. When the indicator has changed to "green", it takes 20 minutes until the stove starts to regulate the combustion process. This period is necessary to obtain the required bed of embers.

General experience and recommendations:

Innovative components

Rikatronic (V)

- If the indicator changes from "green" to "red – flashing“ then this is the time to add more wood logs.
- After adding fuel for the first time fully close the shaker grate.
- The "red – flashing" phase varies according to the respective environmental influences, as a rule, however, it lasts approx. 5 – 10 min. After that the indicator changes to steady green and indicates the main combustion phase.
- Also eco-operation with reduced heat output is possible, if the space to be heated is already at the desired temperature. To activate the eco-operation you have to press a button called "Eco – button".

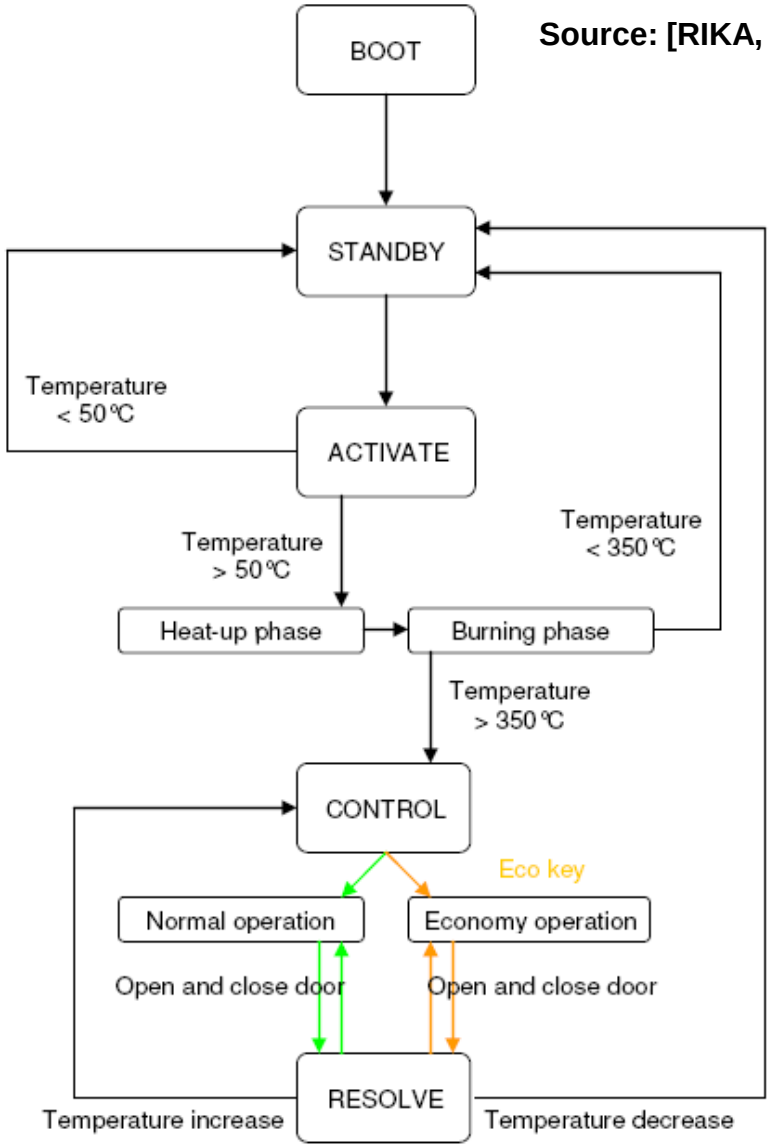
Source: [RIKA, 2010]

General experience and recommendations:

Innovative components
Rikatronic (VI)

Functional specification

- Boot phase
- Stand-by phase
- Activate phase
  - Heat-up phase
  - Burning phase
- Control phase
  - Normal operation
  - Eco-operation
- Resolve phase



Source: [RIKA, 2010]

General experience and recommendations:

Innovative components
i-control

- intelligent-control (i-control) developed by Haas & Sohn
- Air control system
- Similar system to Rikatronic.
- For each phase of combustion the microprocessor-based control supplies the optimum quantity of air for the combustion process.
- This is done in steps in dependence of the flue gas temperature measured at the outlet of the chimney stove.
- 1 type of chimney stove (i-control 247.17) with i-control technology is available.
- No detailed functional description available at the moment.

Research findings:
Chimney stoves

Ignition and operation of a chimney stove (I):

- Impact of different ignition strategies
  - There was no special focus on this impact during research activities in Austria.
  - It was found that significant differences regarding the gaseous (CO and OGC) and particulate emissions during the ignition batch can occur even when the same strategy is used.
  - Emission factors determined for the ignition batch using the same ignition strategy varied as following:
    - CO: 1,490 to 6,140 mg/MJ
    - OGC: 119 to 920 mg/MJ,
    - PM_1: 74 to 173 mg/MJ

Research findings:
Chimney stoves

Ignition and operation of a chimney stove (II):

- Wood log size and shape effects
  - There was no special focus on this impact during the research activities so far.
  - Within the scope of research performed the wood log size and shape recommended by the manufacturers was used.
- Fuel type differences
  - There was no special focus on this impact during research activities so far.
  - Within the scope of research performed the fuel type (mainly beech) recommended by the manufacturers was used.
- Fuel moisture impacts
  - There was no special focus on this impact during the research activities so far.
  - BE2020+ indents to perform some investigations concerning the influence of the fuel moisture content within the FutureBioTec project.

Research findings:
Chimney stoves

Ignition and operation of a chimney stove (III):

- Impacts of frequency of re-charging
  - There was no special focus on this impact during the research activities so far.
  - Within the scope of research performed the frequency of recharging recommended by the manufacturers was used.
- Fuel loading differences
  - There was no special focus on this impact during the research activities so far.
  - Within the scope of research performed the mass of fuel recommended by the manufacturers was used.
- Impacts concerning re-charging mode
  - There was no special focus on this impact during the research activities so far.
  - Within the scope of research performed the recharging mode recommended by the manufacturer was applied.

Research findings:
Chimney stoves

Ignition and operation of a chimney stove (IV):

- Performance with wood briquettes compared to wood logs
  - Test run data with wood briquettes are not available.
  - Within the scope of research performed only wood logs were used.
- Performance with automatic air control
  - See **Project A – Development of a new stove technology**

Research findings:
Chimney stoves

Project A –Development of a new stove technology (I)

- Overall project aim: Development of a new stove technology with reduced emissions compared with the state-of-the-art.
- Methodology applied
  - Performance of test runs to determinate the gaseous and particulate emissions to evaluate the current situation
  - CFD based optimisation of the stove geometry
  - Development of a CFD model suitable for the simulation of combustion batches in stoves (Scharler et. al, 2009)
  - Development of an appropriate “intelligent” process control
  - Performance of test runs with the optimised stove (prototype)
    - Test runs with controlled combustion
    - Test runs with uncontrolled combustion

Research findings:
Chimney stoves

Project A – Development of a new stove technology (II)

- Continuous measurements
  - Operation parameters: flue gas temperature, combustion chamber temperature, chimney draught
  - Flue gas composition in the flue gas by using standard flue gas analysers for O_2 (paramagnetic sensor), CO (NDIR), NO_x (CLD) and OGC (FID)
  - Determination of the particle size distribution (PSD) and the concentration of aerosols in the diluted flue gas with an electrical low-pressure impactor (ELPI 10 lpm)
  - Determination of the air volume flows (only during selected batches and only if these measurements do not significantly disturb the combustion process due to increased pressure losses)

Research findings:
Chimney stoves

Project A – Development of a new stove technology (III)

- Discontinuous measurements
  - Weighing of the fuel and weighing of the bottom ash
  - Determination of the total fly ash (TSP) concentration in the undiluted flue gas according to VDI 2066
  - Determination of the PSD and the concentration of aerosols in the diluted flue gas with 9-stage Berner-type low-pressure impactors (BLPI)

Research findings:
Chimney stoves

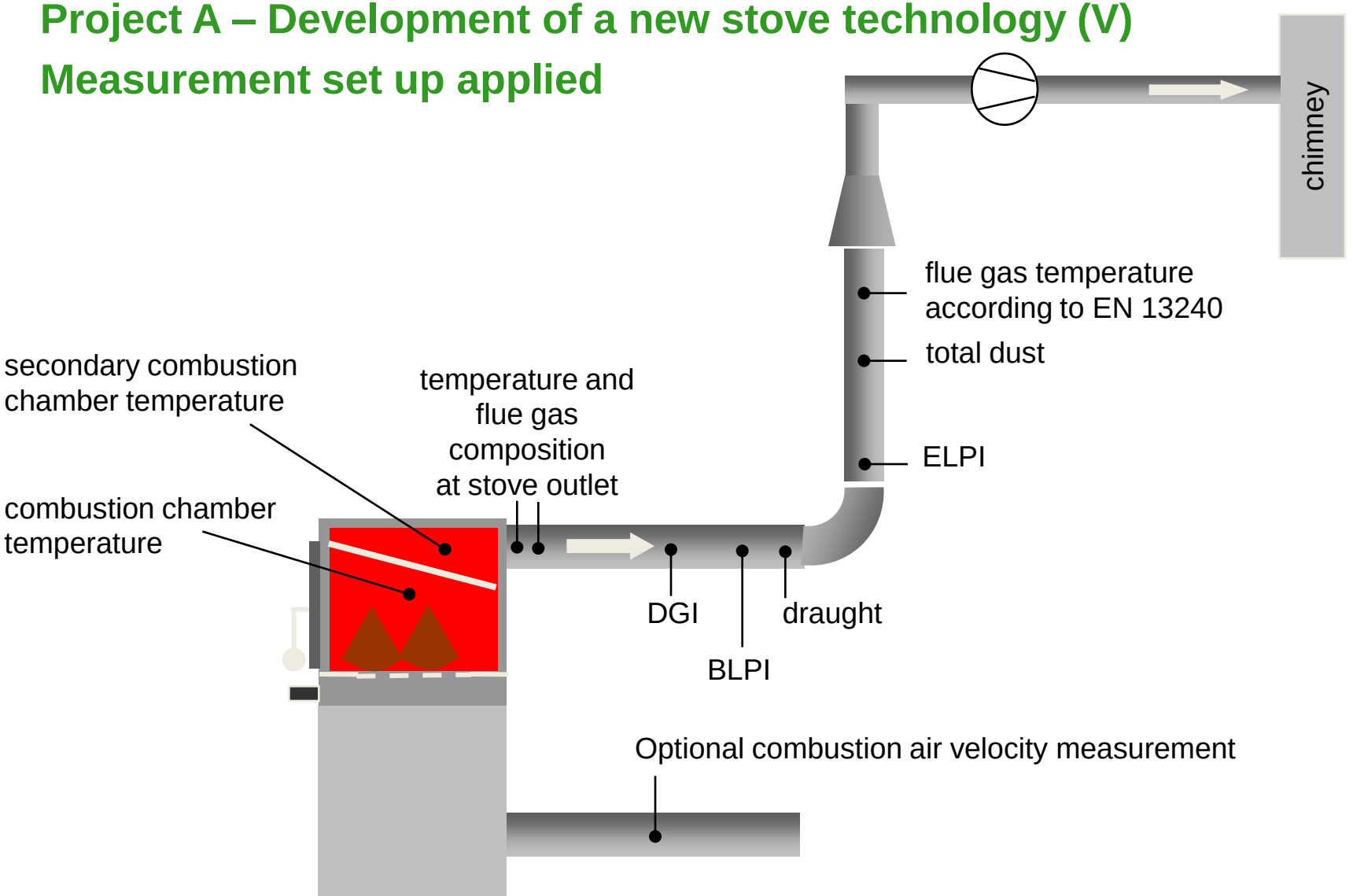
Project A – Development of a new stove technology (IV)

- Ignition and operation of the stove as recommended by the manufacturer
- Nominal load: 8 kW
- Used fuel: beech logs (33 cm) according to ÖNORM M 7132 and ÖNORM CEN/TS 14961
- Moisture content: 9,8 wt.% (w.b.)
- Re-charging: after extinction of the flame
- Test runs
  - Ignition batch + 2 batches to reach steady conditions (heating-up phase)
  - 3 batches under steady conditions (evaluated phase)

Research findings:
Chimney stoves

Project A – Development of a new stove technology (V)

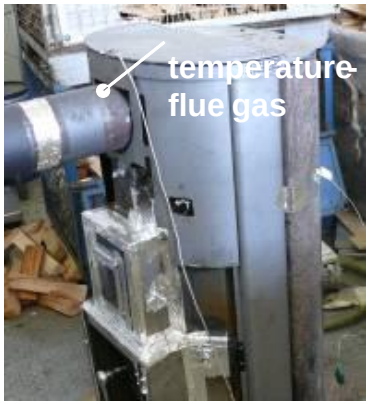
Measurement set up applied

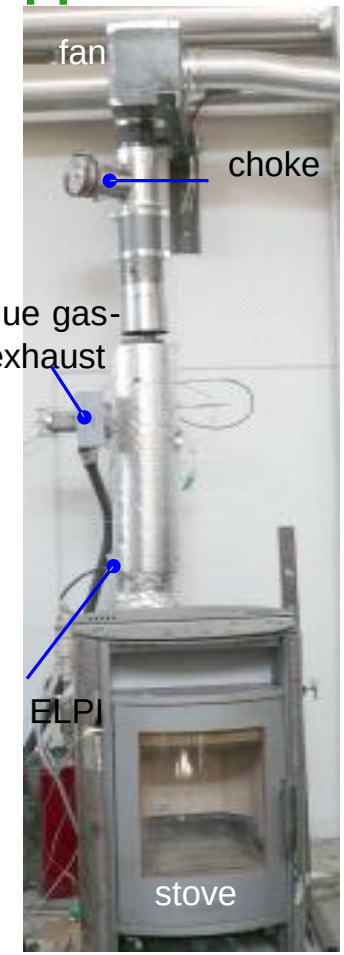


Research findings:
Chimney stoves

Project A – Development of a new stove technology (VI)

Measurement set up applied





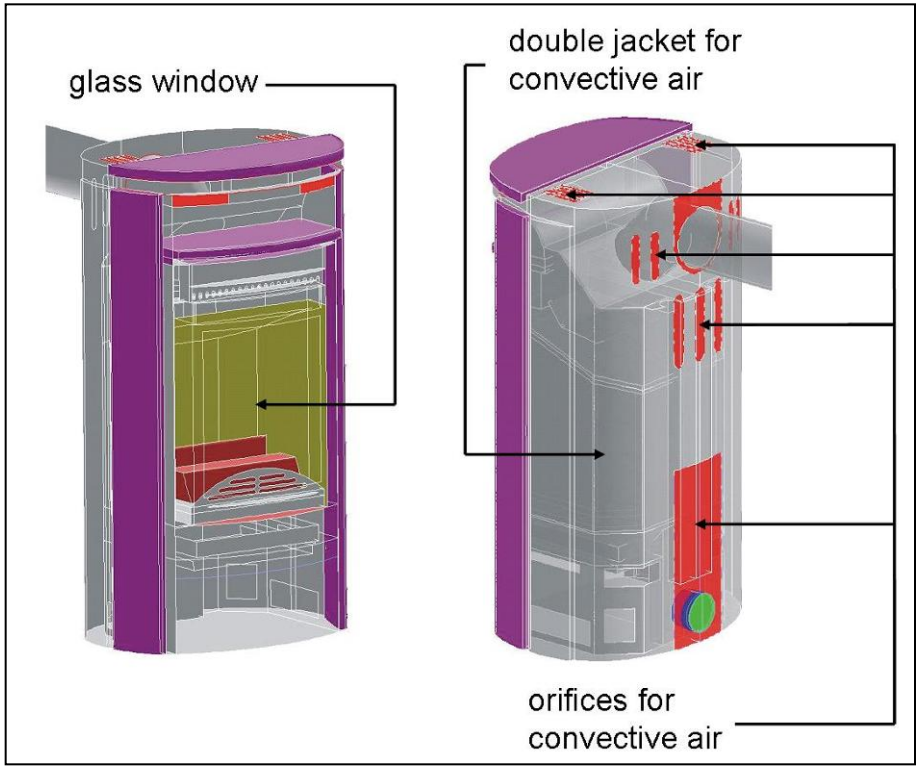
Research findings:
Chimney stoves

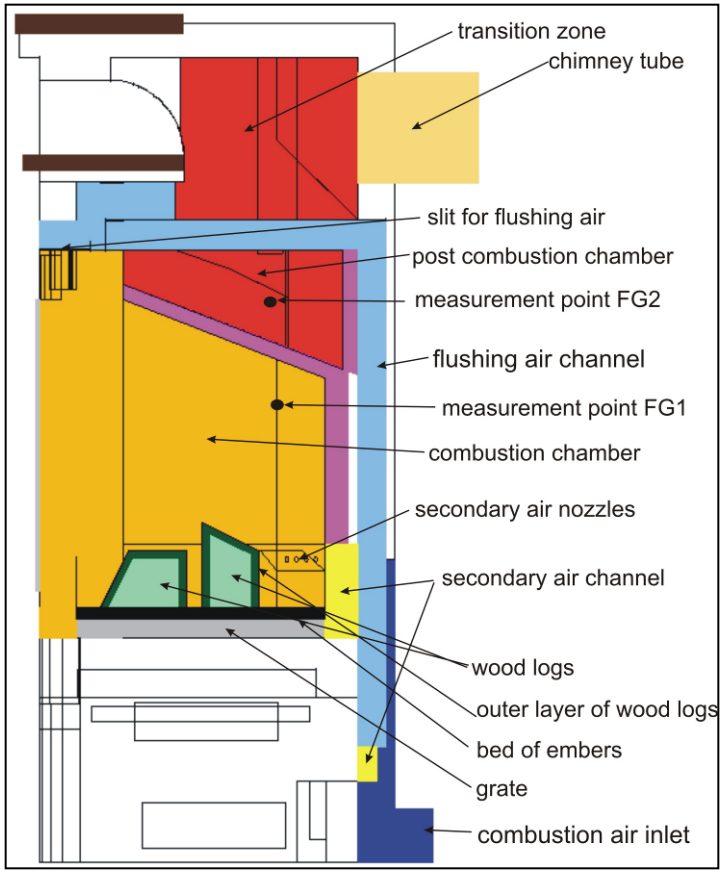
Project A – Development of a new stove technology (VII)

- CFD based optimisation of the stove by optimisation of the stove geometry and air staging measures (see pictures on slide 57 and 58)
  - Installation of secondary air nozzles.
- Optimisation by development of an intelligent process control
  - Measurement of the flue gas temperature by a resistance temperature sensor (Pt 100).
  - Estimation of the combustion temperature by a 1st order dynamical model from the measured temperature.
  - Determination of the current combustion process on the basis of the calculated combustion temperature and its first and second derivatives.
  - Positioning of the air dampers according to the current combustion process.

Research findings:
Chimney stoves

Project A – Development of a new stove technology (VIII)

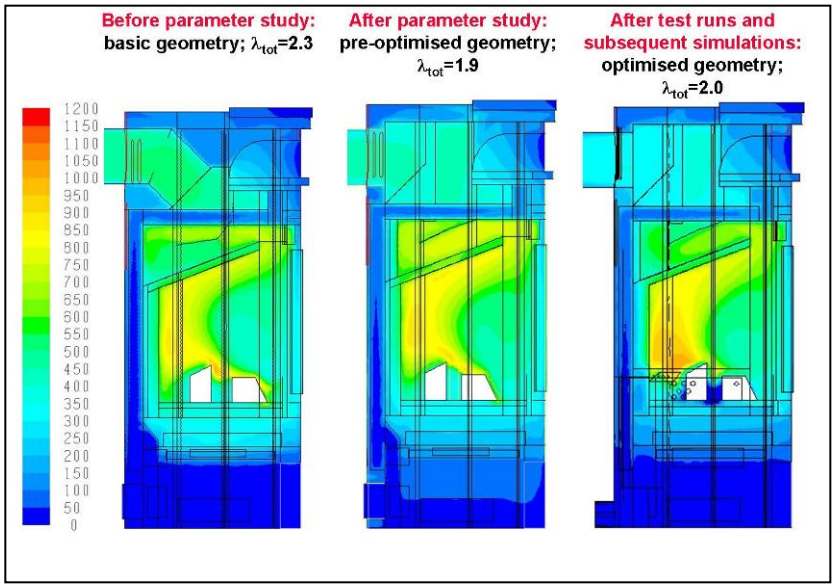




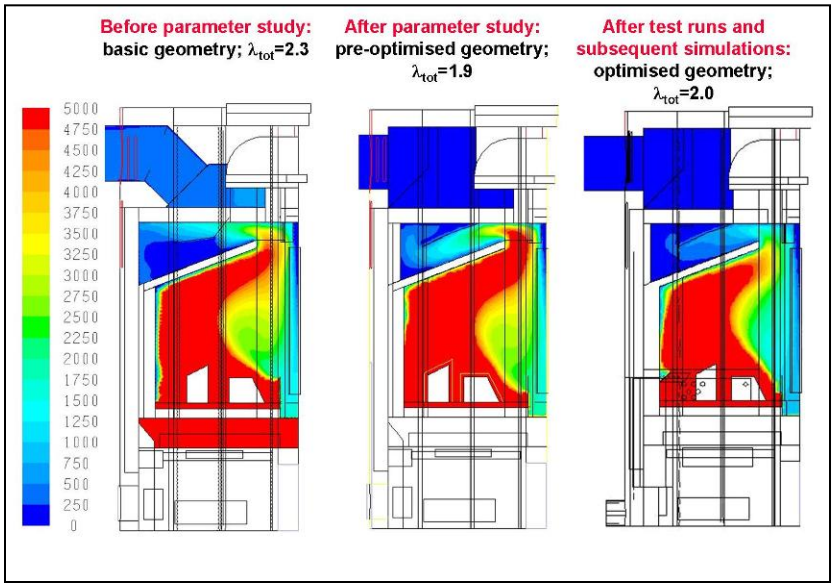
Geometry of the wood log fired stove

Research findings:
Chimney stoves

Project A – Development of a new stove technology (IX)



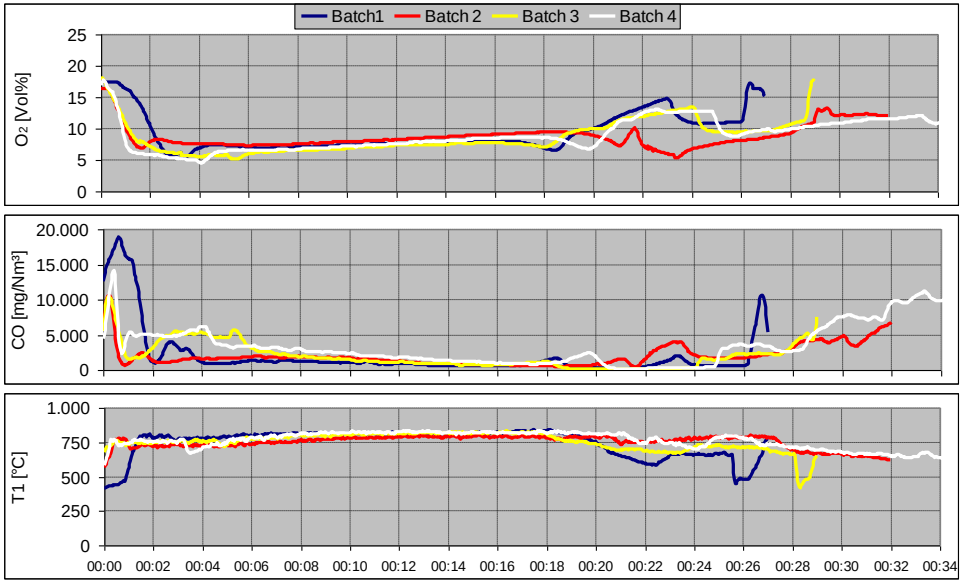
Selected simulation results: iso-surfaces of combustion and convective air temperature, flue gas and stove materials [°C] in the vertical symmetry plane of the stove

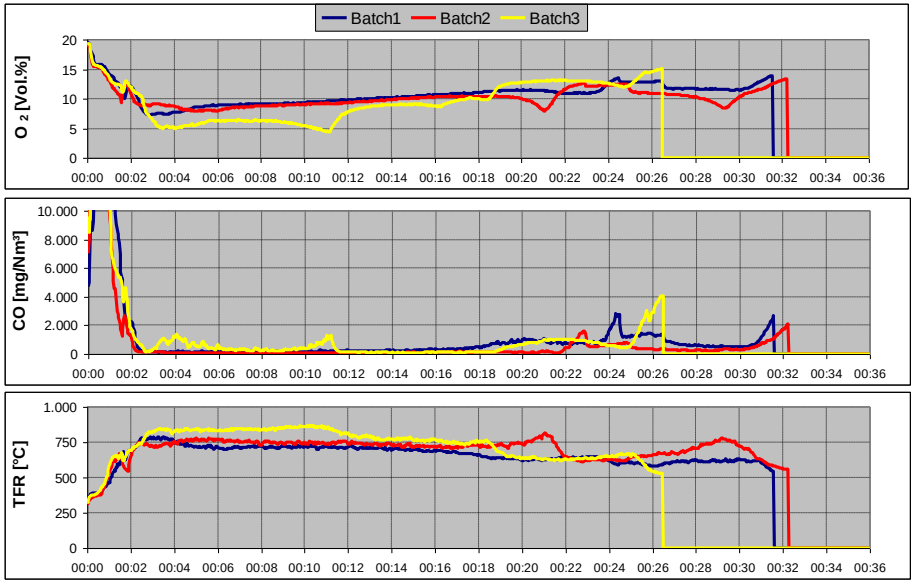


Selected results: iso-surfaces of CO concentrations [ppmv] in the flue gas in the vertical symmetry plane of the stove

Research findings:
Chimney stoves

Project A – Development of a new stove technology (XI)





Explanations: left diagram …status by project start, right diagram: … Emission results: status after optimisation measures, data related to dry flue gas and 13 vol. % O_2; T1 and TFR … combustion chamber temperature

Research findings:
Chimney stoves

Project A – Development of a new stove technology (XII)

- Results*
  - Significant reduction of the gaseous and particulate emissions by the optimised stove geometry and air staging measures (see also diagrams on slide 59).
  - Short ignition phase is achieved which means, that high flue gas temperatures and low O_2-concentrations in the flue gas are reached within short time.
  - During the main combustion phase optimised mixing of the gases released from the wood logs with the combustion air lead to improved burnout

conditions	CO [mg/MJ]	OGC [mg/MJ]	PM1 [mg/MJ]	TSP [mg/MJ]
Project start	1,368	55	28.1	45.7
After optimisation	449	16	16.3	18.9
Prototype	413	13	14.6	25.5

*)... Calculations according to EN 13240, for the calculations the mean O_2-values as well as the mean gaseous emission values (ppm) will be considered. Period of calculation: Closing the door until no flame is recognisable.

Research findings:
Chimney stoves

Project B - Test runs with a modern Austrian and a low price chimney stove from the hardware store (I)

- Modern stove: represents the state-of-the-art in Austria
- Low price stove: represents a stove with antiquated technology
- Test runs with both types of stoves
  - Ignition batch + 5 batches
  - 2 test runs with both stoves performed
- Determination of gaseous and particulate emissions
- Ignition and operation of the stoves as recommended by the manufacturer
- Nominal load
  - Modern stove: 6 kW
  - Low price stove: 6.5 kW

Research findings:
Chimney stoves

Project B - Test runs with a modern Austrian and a low price chimney stove from the hardware store (II)

- Used fuel
  - beech logs according to ÖNORM M 7132 and ÖNORM CEN/TS 14961
  - moisture content: 8.5 wt.% (modern stove) and 9,4 wt.% (low price stove)
- Continuous measurements
  - Operation parameters: flue gas temperature (T FG), combustion chamber temperature (T CC), chimney draught (dp)
  - Flue gas composition in the undiluted flue gas by using standard flue gas analysers for O_2 (paramagnetic sensor), CO (NDIR), NO_x (CLD) and OGC (FID)
  - Determination of the particle size distribution (PSD) and the concentration of aerosols in the diluted flue gas with an electrical low-pressure impactor (ELPI 10 lpm)
  - All relevant data (temperatures, mass flows) of the dilution air

Research findings:
Chimney stoves

Project B - Test runs with a modern Austrian and a low priced chimney stove from the hardware store (III)

- Discontinuous measurements and sampling
  - Fuel sampling
  - Bottom ash sampling
  - Weighing of the fuel and weighing of the bottom ash
  - Determination of the total fly ash (TSP) concentration in the undiluted flue gas according to VDI 2066
  - Determination of the PSD and the concentration of aerosols in the diluted flue gas with 9-stage Berner-type low-pressure impactors (BLPI)
  - Determination of the PSD and the concentration of aerosols in the diluted flue gas with 5-stage Dekati-gravimetric impactor (DGI)

Research findings:
Chimney stoves

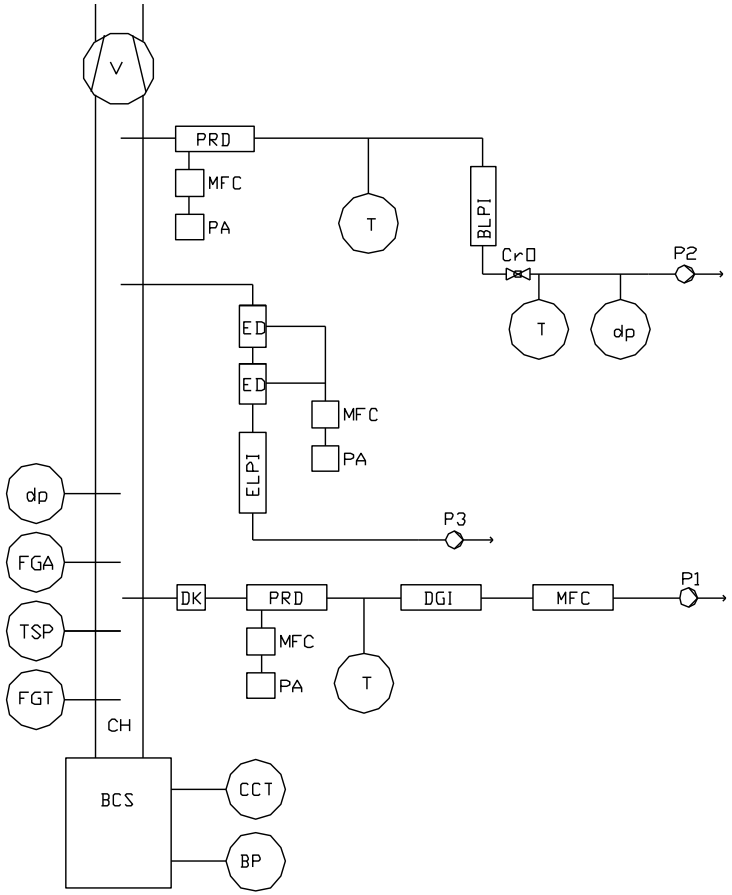
Project B - Test runs with a modern Austrian and a low priced chimney stove from the hardware store (IV)

low price stove

modern stove

Research findings:
Chimney stoves

Project B - Test runs with a modern Austrian and a low priced chimney stove from the hardware store (V) - measurement set up

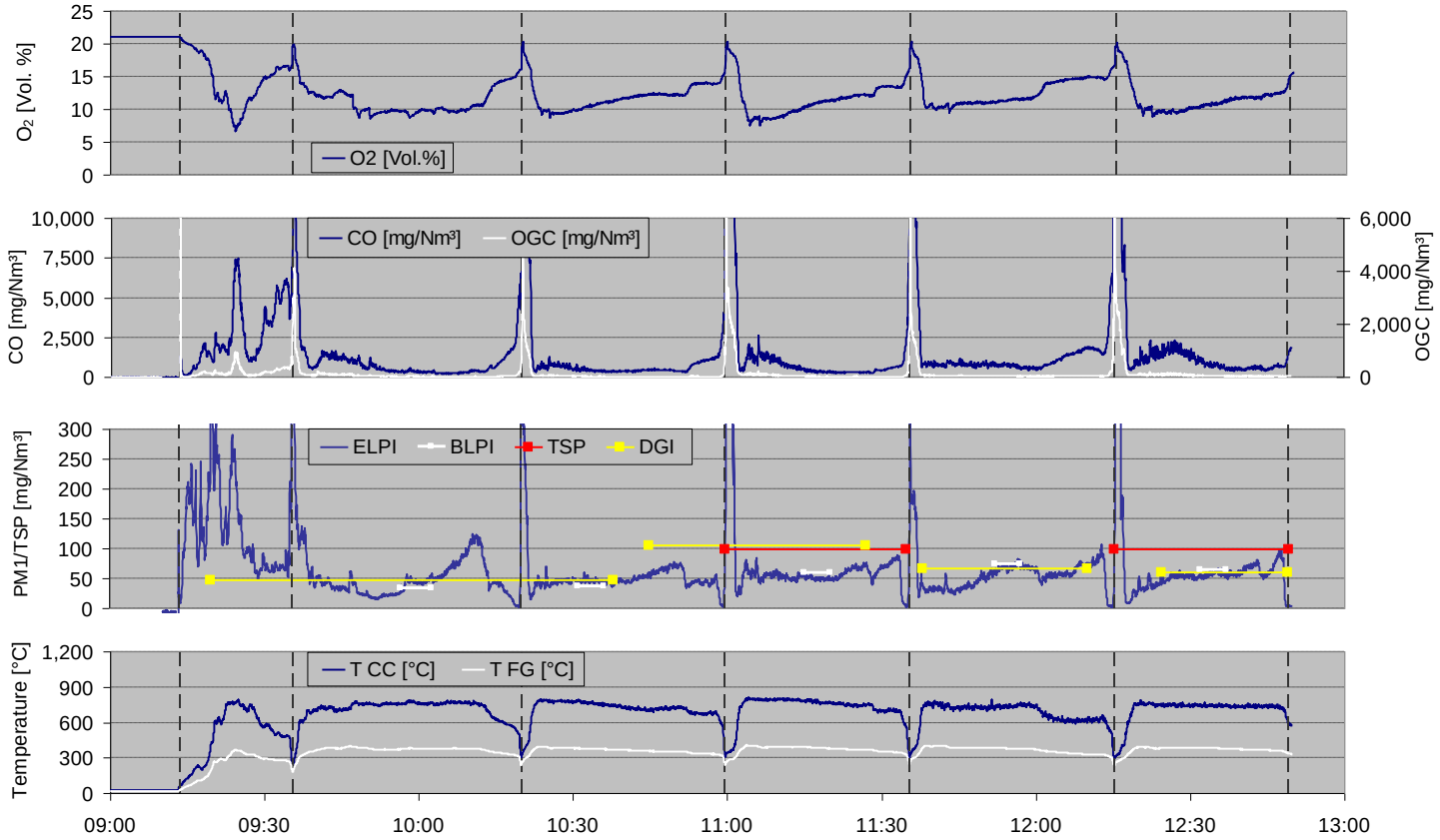


BCS	**biomass combustion system**
CCT	**combustion chamber temperature**
BP	**boiler power**
CH	**chimney**
FGT	**flue gas temperature**
TSP	**total suspended particulate matter**
FGA	**flue gas analyser**
dp	**chimney draught**
DK	**cyclone**
PRD	**porous tube diluter**
PA	**particle free and dry pressurised air**
MFC	**massflow controller**
DGI	**Dekati Gravimetric Impactor**
BLPI	**Berner typ low pressure impactor**
ELPI	**Electrical low pressure impactor**
ED	**ejector-diluter**
P	**pump**
V	**ventilator**
T	**temperature**
Cro	**critical orifice**

Research findings:
Chimney stoves

Project B - Test runs with a modern Austrian and a low priced chimney stove from the hardware store (VI)

Gaseous and particulate emissions during a test run with the modern chimney stove.

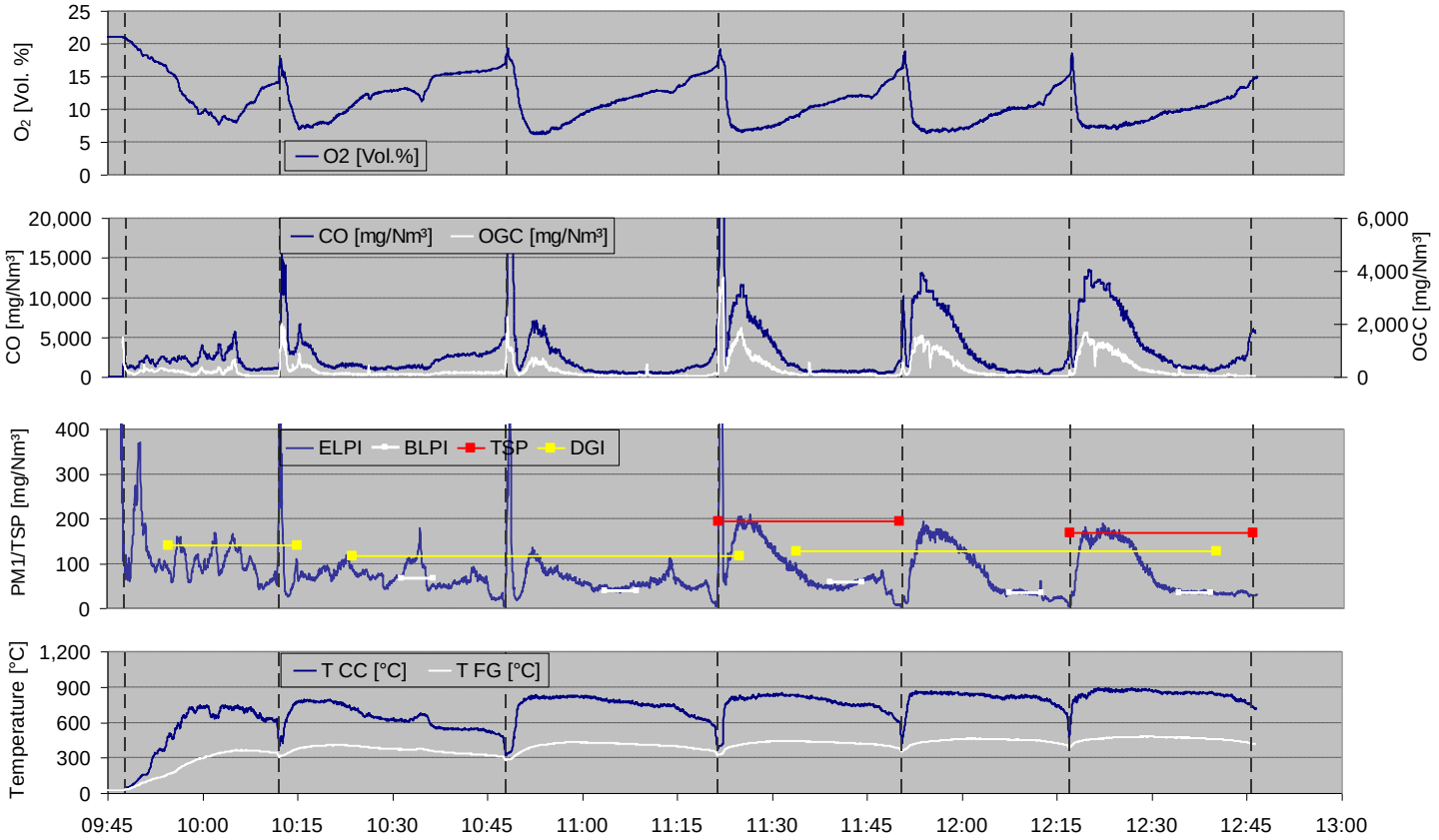


Emission results: data related to dry flue gas and 13 vol. % O_2; T CC … combustion chamber temperature; T FG … flue gas temperature; the BLPI, TSP and DGI lines indicate the measured PM concentration over the respective sampling period.

Research findings:
Chimney stoves

Project B - Test runs with a modern Austrian and a low priced chimney stove from the hardware store (VII)

Gaseous and particulate emissions during a test run with the low price chimney stove.



Emission results: data related to dry flue gas and 13 vol. % O_2; T CC … combustion chamber temperature; T FG … flue gas temperature; the BLPI, TSP and DGI lines indicate the measured PM concentration over the respective sampling period.

Research findings:
Chimney stoves

Project B - Test runs with a modern Austrian and a low priced chimney stove from the hardware store (VIII)

- Results
  - Modern chimney stoves emit significantly less gaseous and particulate emissions than older (low price chimney stove) technologies.
  - The old technology stove emits much more gaseous and particulate emissions during all phases of combustion (ignition phase, main combustion and the burnout phase).
  - Modern stoves are characterised by a short ignition phase and quite stable O_2 concentrations in the flue gas as well as sufficiently high temperatures during the main combustion phase.
  - Also during charcoal burnout the modern stove emits much less gaseous and particulate emissions than the old technology.

Research findings:
Chimney stoves

Project B - Test runs with a modern Austrian and a low priced chimney stove from the hardware store (IX)

- Results *

Batch 3-5	modern stove			low price stove		
	mean	min	max	mean	min	max
CO [mg/MJ]	605.9	439.5	820.1	2527.6	2399.7	3429.8
OGC [mg/MJ]	41.6	27.2	56.6	231.9	208.3	313.0
PM_1 [mg/MJ]	43.6	38.7	47.6	63.7	53.5	79.0
TSP [mg/MJ]	70.1	65.3	81.5	113.0	101.4	129.3

	modern stove		low price stove	
	test run 1	test run 2	test run 1	test run 2
CO [mg/MJ]	789.7	729.5	2724.0	2252.3
OGC [mg/MJ]	51.4	47.9	278.3	209.6
PM_1 [mg/MJ]	47.2	46.1	74.2	55.5
TSP [mg/MJ]	74.7	65.5	105.2	120.8

*)... Calculations according to EN 13240, for the calculations the mean O_2-values as well as the mean gaseous emission values (ppm) are considered. Period of calculation: Closure of door until flame extinction.

Research findings:
Slow heat releasing stoves

Project A - Test runs with a modern tiled stove (I)

- 6 Test runs with a modern tiled stove performed
- Used fuel
  - beech logs (25 cm) according ÖNORM M 7132 and ÖNORM CEN/TS 14961
  - moisture content: 9.1 wt.% (w.b.)
- Nominal load: 4.2 kW
- Stove fitter: member of the Austrian tiled stove association
- Fuel mass for nominal load: 10.3 kg
- Determination of gaseous and particulate emissions
- Ignition and operation of the stove as recommended by the manufacturer

Research findings:
Slow heat releasing stoves

Project A - Test runs with a modern tiled stove (II)

- Continuous measurements
  - Operation parameters: flue gas temperature (T FG), combustion chamber temperature (T CC), chimney draught (dp)
  - Flue gas composition in the undiluted flue gas by using standard flue gas analysers for O_2 (paramagnetic sensor), CO (NDIR), NO_x (CLD) and OGC (FID)
  - Determination of the particle size distribution (PSD) and the concentration of aerosols in the diluted flue gas with an electrical low-pressure impactor (ELPI 10 lpm)
  - All relevant data (temperatures, mass flows) of the dilution air

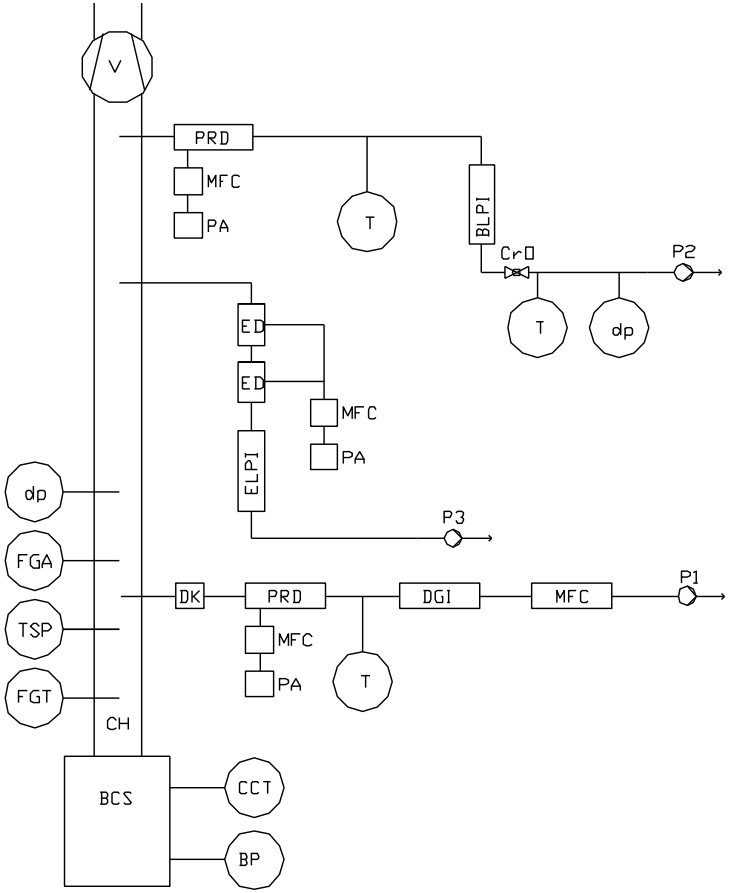
Research findings:
Slow heat releasing stoves

Project A - Test runs with a modern tiled stove (III)

- Discontinuous measurements and sampling
  - Fuel sampling
  - Bottom ash sampling
  - Weighing of the fuel and weighing of the bottom ash
  - Determination of the total fly ash (TSP) concentration in the undiluted flue gas according to VDI 2066
  - Determination of the PSD and the concentration of aerosols in the diluted flue gas with 9-stage Berner-type low-pressure impactors (BLPI)
  - Determination of the PSD and the concentration of aerosols in the diluted flue gas with a 5-stage Dekati-gravimetric impactor (DGI)

Research findings:
Slow heat releasing stoves

Project A - Test runs with a modern tiled stove (IV) -measurement set up

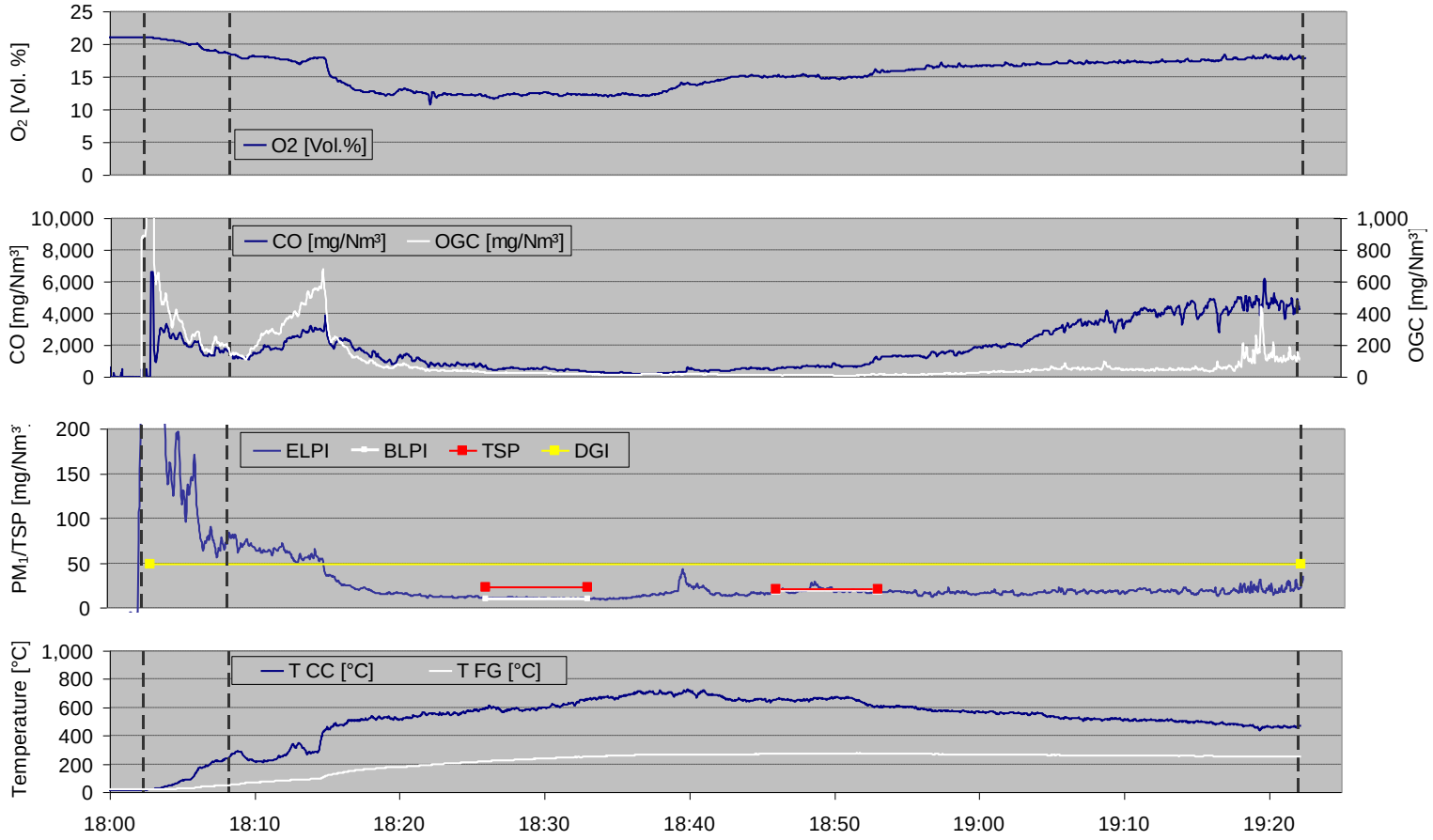


BCS	**biomass combustion system**
CCT	**combustion chamber temperature**
BP	**boiler power**
CH	**chimney**
FGT	**flue gas temperature**
TSP	**total suspended particulate matter**
FGA	**flue gas analyser**
dp	**chimney draught**
DK	**cyclone**
PRD	**porous tube diluter**
PA	**particle free and dry pressurised air**
MFC	**massflow controller**
DGI	**Dekati Gravimetric Impactor**
BLPI	**Berner typ low pressure impactor**
ELPI	**Electrical low pressure impactor**
ED	**ejector-diluter**
P	**pump**
V	**ventilator**
T	**temperature**
Cro	**critical orifice**

Research findings:
Slow heat releasing stoves

Project A - Test runs with a modern tiled stove (V)

Gaseous and particulate emissions during a test run with a modern tiled stove.



Emission results: data related to dry flue gas and 13 vol. % O_2; T CC … combustion chamber temperature; T FG … flue gas temperature; the BLPI, TSP and DGI lines indicate the measured PM concentration over the respective sampling period.

Research findings:
Slow heat releasing stoves

Project A - Test runs with a modern tiled stove (VI)

- Results*

	CO [mg/MJ]	OGC [mg/MJ]	PM_1 [mg/MJ]	TSP [mg/MJ]
test run 1	898.9	37.5	45.4	14.1
test run 2	912.0	28.3	30.0	13.1
test run 3	793.3	31.0	37.8	14.8
test run 4	902.0	25.3	18.4	11.5
test run 5	683.4	24.6	22.1	15.6
test run 6	833.3	35.0	24.0	25.6
mean	837.1	30.3	29.6	15.8
min	683.4	24.6	18.4	11.5
max	912.0	37.5	45.4	25.6

*)... Calculations according to EN 13240, for the calculations the mean O_2-values as well as the mean gaseous emission values (ppm) are considered. Period of calculation: Igniting until flame extinction. TSP measurements performed during steady conditions in the mean combustion phase → see diagram on slide 74.

Classification, performance and limitations of individual furnaces for wood ("room heaters") (I)

					Significance of furnace		National test method or standard (if applicable)	Official national limits				
Name*	Other denominations	European test standard	Year	Description (according to EN-standard)	Sold 2008 [5]	Relative share (%)		Relevant directive or regulation	Minimum efficiency %	CO (mg/MJ)	NO_x (mg/MJ)	OGC (mg/MJ)	Total PM (mg/MJ)
Open fires	Open fireplace	EN 13229	Oct. 2005	Stand-alone or inserted furnace without any change of functional design, without door	n.a.		none	none	-	-	-	-	-
Roomheaters with "flat" furnace	Closed fireplaces	EN 13240	Oct. 2005	Inserted furnace without functional changes	26.000	55%	none	Art. 15 a B-VG [1]	78	1.100	150 [3]	80	60
	Chimney stoves (with or without window)			Stand-alone furnace without any change of functional design			none	Art. 15 a B-VG [1]	78	1.100	150 [3]	80	60
Roomheaters with "filling" furnace	Chimney stoves (with or without window)	EN 13240	Oct. 2005	Burning time with wood: 1,5 h or 10 h, resp. (nominal heat power or low power adjustment)			none	Art. 15 a B-VG [1]	78	1.100	150 [3]	80	60
Slow heat release appliances	Mansionry heaters (e.g. heavy tiled or plastered stoves - errected on-site from modules and storage materials)	EN 15250/A1	June 2007	Furnace with heat release even when the fire is extinct; either as pre-fabricated unit or as manufacturer-released set of pre-manufactured parts (no on-site realization by craftsman, no water jacket)	n.a.		none	Art. 15 a B-VG [1]	78	1.100	150 [3]	80	60
Inset appliances (closed operation)	Closed fireplace	EN 13229	Oct. 2005	Stand-alone or built-in furnace with functional changes	n.a.		none	Art. 15 a B-VG [1]	78	1.100	150 [3]	80	60
Tiled stove inserts with "flat" furnace	Warm air tiled stove inserts	EN 13229/A1	Oct. 2005	Heating insert for tiled or plastered stoves until 15 kW, without water jacket, for small single layer fuel chargings	14.500	31%	none	Art. 15 a B-VG [1]	78	1.100	150 [3]	80	60
Tiled stove inserts with "filling" furnace	Warm air tiled stove inserts	EN 13229/A1	Oct. 2005	Heating insert for tiled or plastered stoves until 15 kW, without water jacket, for high multi-layer fuel chargings			none	Art. 15 a B-VG [1]	78	1.100	150 [3]	80	60
Residential cookers	- Kitchen stove or - Cooking & baking oven	EN 12815	Sept. 2005	Furnace with cooking as main function and further benefits by heat release to the room	3.500	7%	none	Art. 15 a B-VG [1]	73° / 70°°	1.100	150 [3]	80	60
Central heating & residential cookers	Central heating & cooking stoves	EN 12815	Sept. 2005	Furnace with cooking as main function and further benefits by heat release to the room and to the hot water circulation	n.a.		none	Art. 15 a B-VG [1]	73° / 70°°	1.100	150 [3]	80	60
Tap water heaters	Bathroom stoves (usually for coal)	DIN 18889	-	-	n.a.		none	none	-	-	-	-	-
Sauna stoves	Sauna stoves	-	-	-	n.a.		none	none	-	-	-	-	-
Residential space heating appliances fired by wood pellets without water jacket	Pelletstoves without water jacket	EN 14785	Sept. 2005	Room heaters for wood pellets until 50 kW, with mechanical fuel charging, without water jacket	3.045	6%	none	Art. 15 a B-VG [1]	78	500 [2]	150 [3]	40	60
Residential space heating appliances fired by wood pellets with water jacket	Pelletstoves with water jacket	EN 14785	Sept. 2005	Room heaters for wood pellets until 50 kW, with mechanical fuel charging, with water jacket			none	Art. 15 a B-VG [1]	78	500 [2]	150 [3]	40	60

Classification, performance and limitations of individual furnaces for wood ("room heaters") (II)

					National quality labels					
Name*	Other denominations	European test standard	Year	Description (according to EN-standard)	Name of Label	Minimum efficiency %	CO (mg/MJ)	NO_x (mg/MJ)	OGC (mg/MJ)	Total PM (mg/MJ)
Open fires	Open fireplace	EN 13229	Oct. 2005	Stand-alone or inserted furnace without any change of functional design, without door	-	-	-	-	-	-
Roomheaters with "flat" furnace	Closed fireplaces	EN 13240	Oct. 2005	Inserted furnace without functional changes	UZ 37 [4]	80	700	120	50	30
	Chimney stoves (with or without window)			Stand-alone furnace without any change of functional design	UZ 37 [4]	80	700	120	50	30
Roomheaters with "filling" furnace	Chimney stoves (with or without window)	EN 13240	Oct. 2005	Burning time with wood: 1,5 h or 10 h, resp. (nominal heat power or low power adjustment)	UZ 37 [4]	80	700	120	50	30
Slow heat release appliances	Mansionry heaters (e.g. heavy tiled or plastered stoves - errected on-site from modules and storage materials)	EN 15250/A1	June 2007	Furnace with heat release even when the fire is extinct; either as pre-fabricated unit or as manufacturer-released set of pre-manufactured parts (no on-site realization by craftsman, no water jacket)	UZ 37 [4]	80	700	120	50	30
Inset appliances (closed operation)	Closed fireplace	EN 13229	Oct. 2005	Stand-alone or built-in furnace with functional changes	UZ 37 [4]	80	700	120	50	30
Tiled stove inserts with "flat" furnace	Warm air tiled stove inserts	EN 13229/A1	Oct. 2005	Heating insert for tiled or plastered stoves until 15 kW, without water jacket, for small single layer fuel chargings	UZ 37 [4]	80	700	120	50	30
Tiled stove inserts with "filling" furnace	Warm air tiled stove inserts	EN 13229/A1	Oct. 2005	Heating insert for tiled or plastered stoves until 15 kW, without water jacket, for high multi-layer fuel chargings	UZ 37 [4]	80	700	120	50	30
Residential cookers	- Kitchen stove or - Cooking & baking oven	EN 12815	Sept. 2005	Furnace with cooking as main function and further benefits by heat release to the room	UZ 37 [4]	80	700	120	50	30
Central heating & residential cookers	Central heating & cooking stoves	EN 12815	Sept. 2005	Furnace with cooking as main function and further benefits by heat release to the room and to the hot water circulation	UZ 37 [4]	80	700	120	50	30
Tap water heaters	Bathroom stoves (usually for coal)	DIN 18889	-	-	-	-	-	-	-	-
Sauna stoves	Sauna stoves	-	-	-	-	-	-	-	-	-
Residential space heating appliances fired by wood pellets without water jacket	Pelletstoves without water jacket	EN 14785	Sept. 2005	Room heaters for wood pellets until 50 kW, with mechanical fuel charging, without water jacket	UZ 37 [4]	90	120" / 265""	100	6" / 10""	20
Residential space heating appliances fired by wood pellets with water jacket	Pelletstoves with water jacket	EN 14785	Sept. 2005	Room heaters for wood pellets until 50 kW, with mechanical fuel charging, with water jacket	UZ 37 [4]	90	120" / 265""	100	6" / 10""	20

Classification, performance and limitations of individual furnaces for wood ("room heaters") (III)

					Emissions (field tests or expert estimate)									
Name*	Other denominations	European test standard	Year	Description (according to EN-standard)	CO mean (mg/MJ)	CO range (mg/MJ)	NOx mean (mg/MJ)	NOx range (mg/MJ)	Total PM mean (mg/MJ)	Total PM range (mg/MJ)	Total PM_1 mean (mg/MJ)	Total PM_1 range (mg/MJ)	OGC mean (mg/MJ)	OGC range (mg/MJ)
Open fires	Open fireplace	EN 13229	Oct. 2005	Stand-alone or inserted furnace without any change of functional design, without door	-	-	-	-	-	-	-	-	-	-
Roomheaters with "flat" furnace	Closed fireplaces	EN 13240	Oct. 2005	Inserted furnace without functional changes	-	-	-	-	-	-	-	-	-	-
	Chimney stoves (with or without window)			Stand-alone furnace without any change of functional design	605,9	439.5 - 820.1	83,3	65.8 - 91.1	70,1	65.3 - 81.5	36,7	38.7 - 47.6	41,6	27.2 - 56.6
Roomheaters with "filling" furnace	Chimney stoves (with or without window)	EN 13240	Oct. 2005	Burning time with wood: 1,5 h or 10 h, resp. (nominal heat power or low power adjustment)	-	-	-	-	-	-	-	-	-	-
Slow heat release appliances	Mansionry heaters (e.g. heavy tiled or plastered stoves - errected on-site from modules and storage materials)	EN 15250/A1	June 2007	Furnace with heat release even when the fire is extinct; either as pre-fabricated unit or as manufacturer-released set of pre-manufactured parts (no on-site realization by craftsman, no water jacket)	-	-	-	-	-	-	-	-	-	-
Inset appliances (closed operation)	Closed fireplace	EN 13229	Oct. 2005	Stand-alone or built-in furnace with functional changes	-	-	-	-	-	-	-	-	-	-
Tiled stove inserts with "flat" furnace	Warm air tiled stove inserts	EN 13229/A1	Oct. 2005	Heating insert for tiled or plastered stoves until 15 kW, without water jacket, for small single layer fuel chargings	837,1	683.4 - 912.0	n.m.	n.m.	15,8	8,4 - 30.7	29,6	18.4 - 45.4	49,3	24.6 - 37.5
Tiled stove inserts with "filling" furnace	Warm air tiled stove inserts	EN 13229/A1	Oct. 2005	Heating insert for tiled or plastered stoves until 15 kW, without water jacket, for high multi-layer fuel chargings	-	-	-	-	-	-	-	-	-	-
Residential cookers	- Kitchen stove or - Cooking & baking oven	EN 12815	Sept. 2005	Furnace with cooking as main function and further benefits by heat release to the room	-	-	-	-	-	-	-	-	-	-
Central heating & residential cookers	Central heating & cooking stoves	EN 12815	Sept. 2005	Furnace with cooking as main function and further benefits by heat release to the room and to the hot water circulation	-	-	-	-	-	-	-	-	-	-
Tap water heaters	Bathroom stoves (usually for coal)	DIN 18889	-	-	-	-	-	-	-	-	-	-	-	-
Sauna stoves	Sauna stoves	-	-	-	-	-	-	-	-	-	-	-	-	-
Residential space heating appliances fired by wood pellets without water jacket	Pelletstoves without water jacket	EN 14785	Sept. 2005	Room heaters for wood pellets until 50 kW, with mechanical fuel charging, without water jacket	-	-	-	-	-	-	-	-	-	-
Residential space heating appliances fired by wood pellets with water jacket	Pelletstoves with water jacket	EN 14785	Sept. 2005	Room heaters for wood pellets until 50 kW, with mechanical fuel charging, with water jacket	104,3	60 - 159	99,3	73-149	15,3	8.0 - 23.0	-	-	4	1.0 - 8.0

Summary (I)
Regulations concerning emission limits

- Two regulations currently apply to small scale combustion installations in Austria
  - The *"Vereinbarung gemäß Art. 15a B-VG über Schutzmaßnahmen betreffend Kleinfeuerungen"* sets requirements for small combustion installations < 50 kW output.
  - The *"Feuerungsanlagen-Verordnung"*, BGBl. II Nr. 331/1997, which entered into force on the 1st of June 1998, covers installations with a nominal heat capacity above 50 kW.
- For small combustion installations < 50 kW output, the requirements make a distinction between manually and automatically operated appliances and between fossil fuels and biofuels.

Appliance and fuel types		Emission limit value [mg/MJ] [1]			
		CO	NO_x	OGC	Dust
Stoking by hand	Biogenic solid fuels	1,100	150 [2]	80	60
	Fossil solid fuels	1,100	100	80	60
Stocking automatically	Biogenic solid fuels	500 [3]	150 [2]	40	60
	Fossil solid fuels	500	100	40	40

[1] in relation to the energy content (net caloric value) of the fuel used.

[2] The NO_x-limits apply only to wood fired boilers

[3] At partial load with 30% of the nominal heat output, the limit may be exceeded by 50%

Summary (II)
Regulations concerning emission limits

- National quality label – Umweltzeichen 37
- Introduced by the Austrian government, the *"Umweltzeichen 37"* is a voluntary scheme that is based on existing Austrian standards, but with improved emission values.
- There is also a distinction between manually and automatically fed appliances.

	Appliance	Type of fuel	Emission limit value [mg/MJ]						Efficiency [%]
			CO		OGC		NO_x	Dust	
			at nominal load	at partial load	at nominal load	at partial load			
Automatically fed	Boiler	pellet	60	135	3	3	100	15	90
		wood chips	150	300	5	10	120	30	90
	Roomheating	pellet	120	255	6	10	100	20	90
		wood chips	120	255	6	10	100	20	90
Manuelly fed	Boiler	log wood	250	750	30	-	120	30	71.3 + 7.7 log Q_N
	Roomheating	log wood	700	-	50	-	120	30	80

Q_N nominal heat output

Summary (III)
Market development in Austria

- No data is available for in total installed chimney stoves, pellet stoves and cookers.
- Total installed tiled stoves: ~ 480,000 (ÖKV, 2010).
- Sold/installed 2008 (Haneder und Furtner, 2009)
  - 3,500 cookers
  - 26,000 chimney stoves
  - 14,500 tiled stoves
  - 3,045 pellet stoves
- Sold pellet stoves (Haneder und Furtner, 2009; Haneder und Furtner, 2008)
  - 2005: 3,780
  - 2006: 5,640
  - 2007: 1,750 (price increase of pellets)
  - 2008: 3,045

Summary (IV)
Screening of user manuals

- Depending on the manufacturer of the chimney stove and the technology used, different ignition strategies are recommended. During the ignition batch basically all available air supplies are fully or almost fully opened.
- Charge of fuel in one layer. Additional fuel should only be placed on the bed of embers (after estimation of the flame).
- Also after re-charging different strategies regarding air supply are recommended.
- The stoves are generally suitable for burning dry (< 20 wt.% (w.b.)), natural wood and can also be fired with wood briquettes.
- Preferably hard wood logs with a length of approx. 25 or 33 cm should be used depending on the width of the firebox.
- Fuel loading: Wood logs ≈ 1.2 to 2.5 kg (2 logs) per layer depending on the nominal load of the stove.
- The grate should always remain closed and does not have to be operated during combustion takes place.

Summary (V)
Screening of user manuals

- The ash drawer is to be emptied regularly to prevent excessive loading of the grate.
- For operating tiled stoves it is recommended to stack the wood cross-wise in layers into the combustion chamber. In order to achieve stacks of nearly equal height at using different quantities of fuel, stack the wood adequately loose or dense. If the fuel is packed loosely, light it from the bottom, if packed tightly, light the upper third of the stack. Leave the air intake open, after the stove has been successfully heated up.

Summary (VI)
Innovative concepts

- Microprocessor-controlled air control systems
  - Rikatronic developed by RIKA
  - intelligent-control (i-control) developed by Haas & Sohn
  - Main working principle: supply of the optimum quantity of air during the different combustion phases (ignition phase, main combustion phase and burn-out phase) using temperature sensors measuring the flue gas or combustion chamber temperature.

Summary (VII)
Relevant R&D results

- Significant reduction of gaseous and particulate emissions by
  - Implementation of air staging strategies
  - Optimisation of stove (firebox) geometry supported by CFD simulations
- Modern chimney stoves emit significantly less gaseous and particulate emissions than older (low price chimney stove) technologies.
  - Old technology stoves emit considerable higher gaseous and particulate emissions during all phases of combustion (ignition phase, main combustion and the burnout phase).
  - Modern stoves are characterised by a short ignition phase and quite stable O_2 concentrations in the flue gas as well as sufficiently high temperatures during the main combustion phase.
  - Also during charcoal burnout the modern stoves emit less gaseous emissions than old technologies.

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Annex 3

Country report from Germany

Evaluation of emission reduction strategies for stoves: *Operational influences*

Country report TFZ

Prepared by:
Claudia Schön, Hans Hartmann

Room heating systems in operation in Germany

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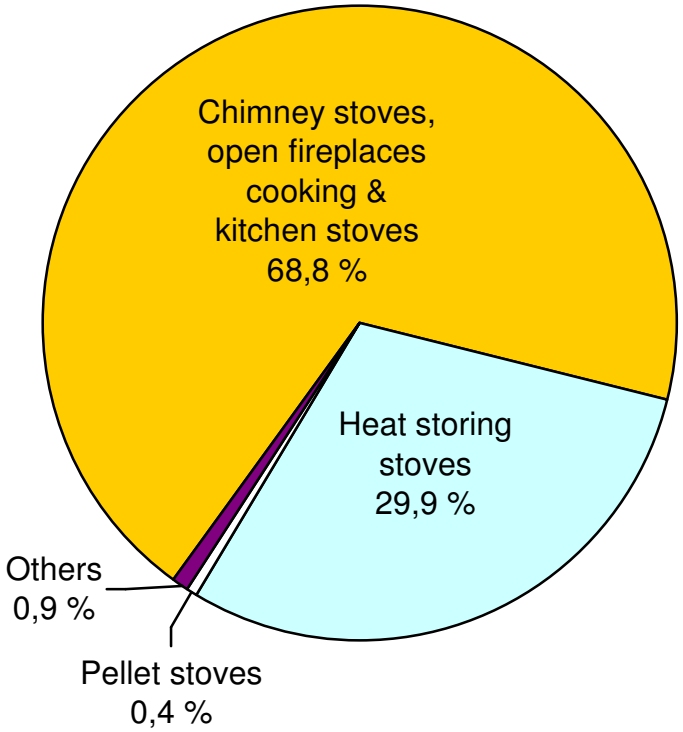
Room heaters: Total 14,1 million (2007)



Source: IE Leipzig

German emission directive: New limitations for room heaters

Requirements for type tests, no inspections by chimney sweep required

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Type	Other denominations	European test standard	Minimum efficiency %	Limits in Step 1 (2010)		Limits in Step 2 (2015)	
				CO (g/m^3_n @13% O_2)	Total PM (g/m^3_n @13% O_2)	CO (g/m^3_n @13% O_2)	Total PM (g/m^3_n @13% O_2)
Open fires	Open fireplace	EN 13229	–	–	–	–	–
Roomheaters with "flat" furnace	Closed fireplaces	EN 13240	73	2,0	0,075	1,25	0,04
	Chimney stoves (with or without window)		73	2,0	0,075	1,25	0,04
Roomheaters with "filling" furnace	Chimney stoves (with or without window)	EN 13240	70	2,5	0,075	1,25	0,04
Slow heat release appliances	Mansionry heaters	EN	75	2,0	0,075	1,25	0,04
Inset appliances (closed operation)	Closed fireplace	EN 13229	75	2,0	0,075	1,25	0,04
Tiled stove inserts with "flat" furnace	Warm air tiled stove inserts	EN 13229/A1	80	2,0	0,075	1,25	0,04
Tiled stove inserts with "filling" furnace	Warm air tiled stove inserts	EN 13229/A1	80	2,5	0,075	1,25	0,04
Residential cookers	- Kitchen stove or - Cooking & baking oven	EN 12815	70	3,0	0,075	1,50	0,04
Central heating & residential cookers	Central heating & cooking stoves	EN 12815	75	3,5	0,075	1,50	0,04
Tap water heaters	Bathroom stoves	-	–	–	–	–	–
Sauna stoves	Sauna stoves	-	–	–	–	–	–
Residential space heating appliances fired by wood pellets without water jacket	Pelletstoves without water jacket	EN 14785	85	0,40	0,05	0,25	0,03
Residential space heating appliances fired by wood pellets with water jacket	Pelletstoves with water jacket	EN 14785	90	0,40	0,03	0,25	0,02

Source: Novelle 1. Bundesimmisionsschutzverordnung vom 26.01.2010

Emission factors for wood furnaces (below 50 kW)
(estimations 2008)

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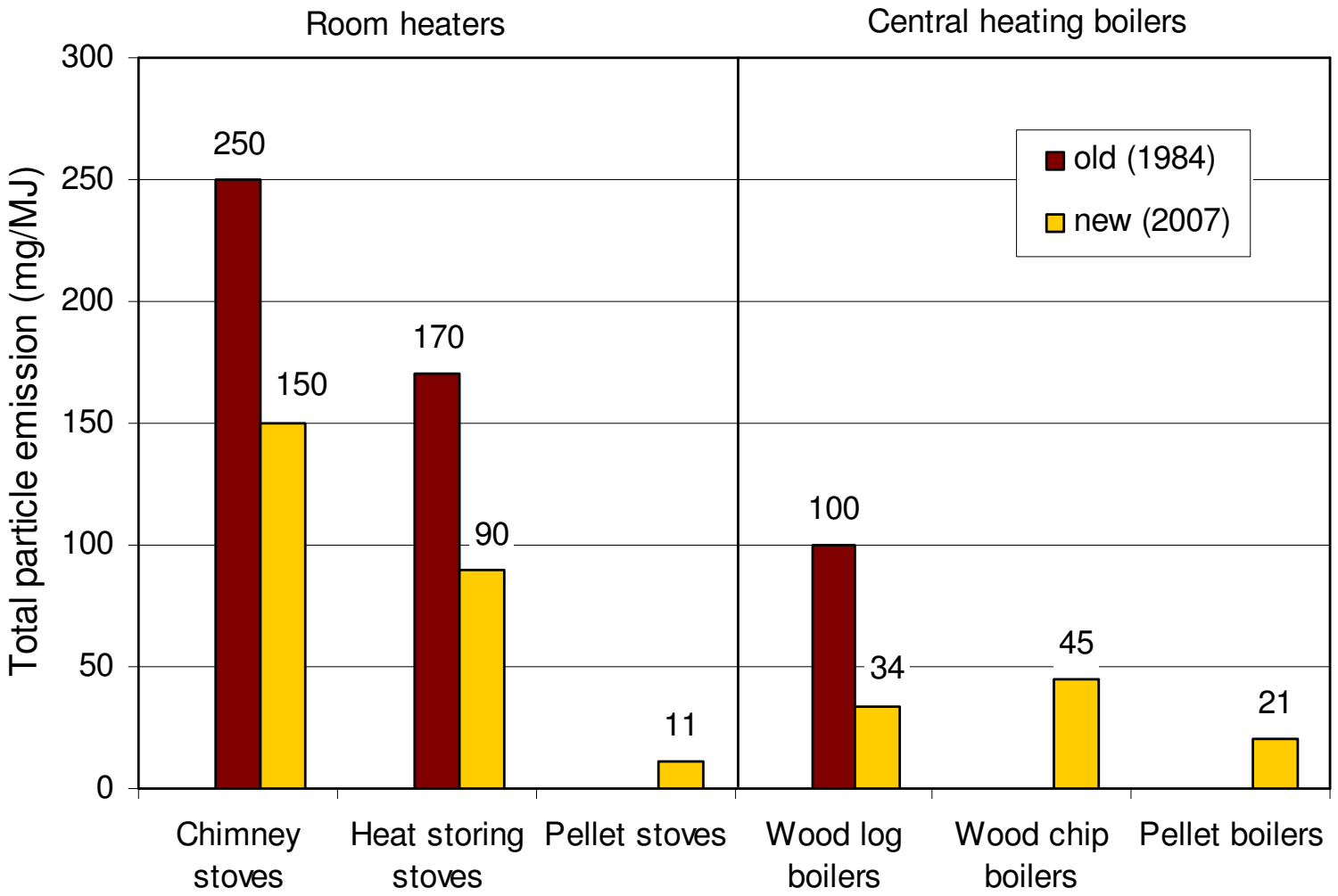

Source: Institut für Energetik, Leipzig, 2008

Type testing versus practise tests

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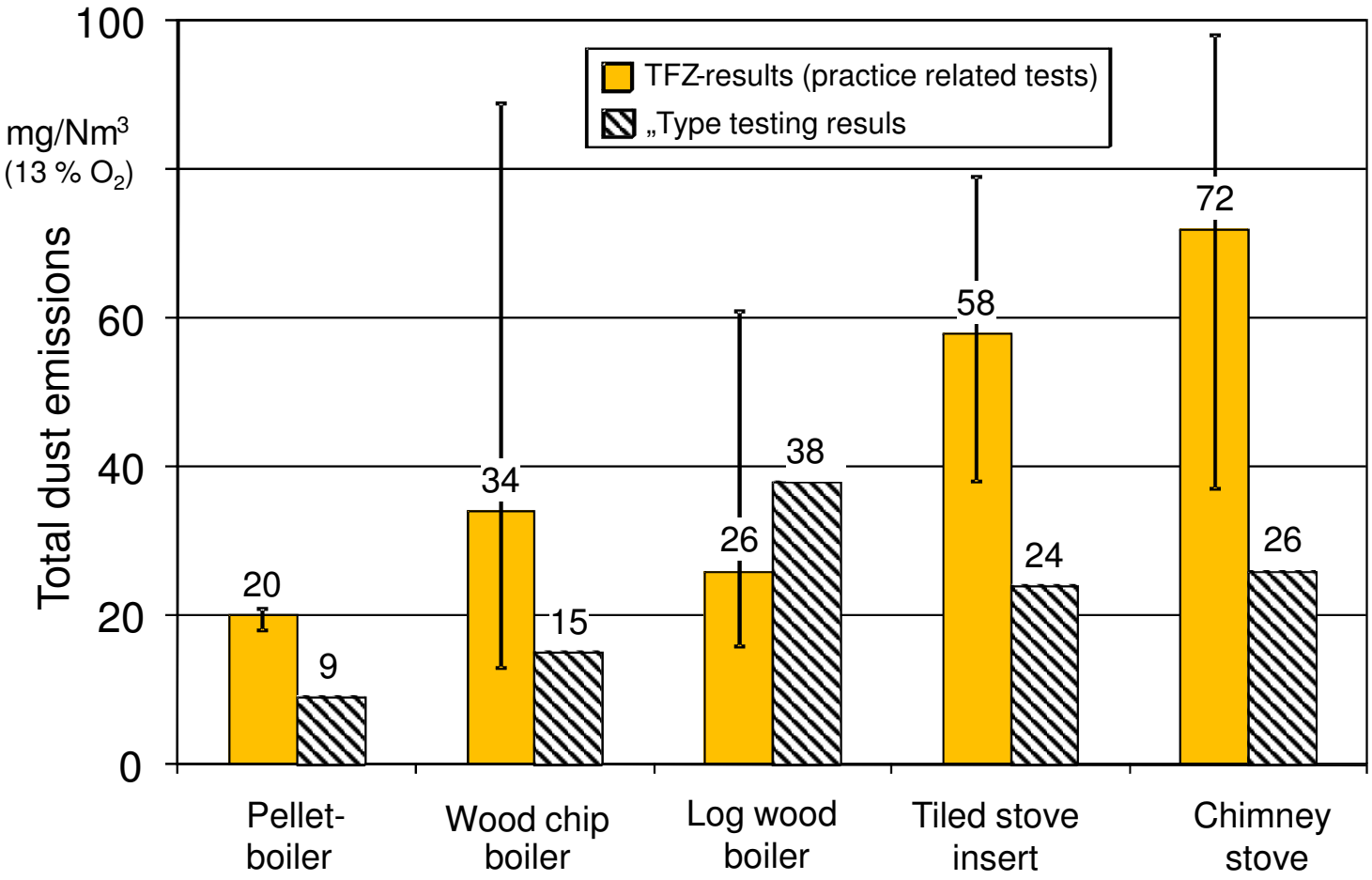

TFZ Measurements: 10 to 12 replications at nominal power, dry fuels

General experience and recommendations:
- Chimney stoves

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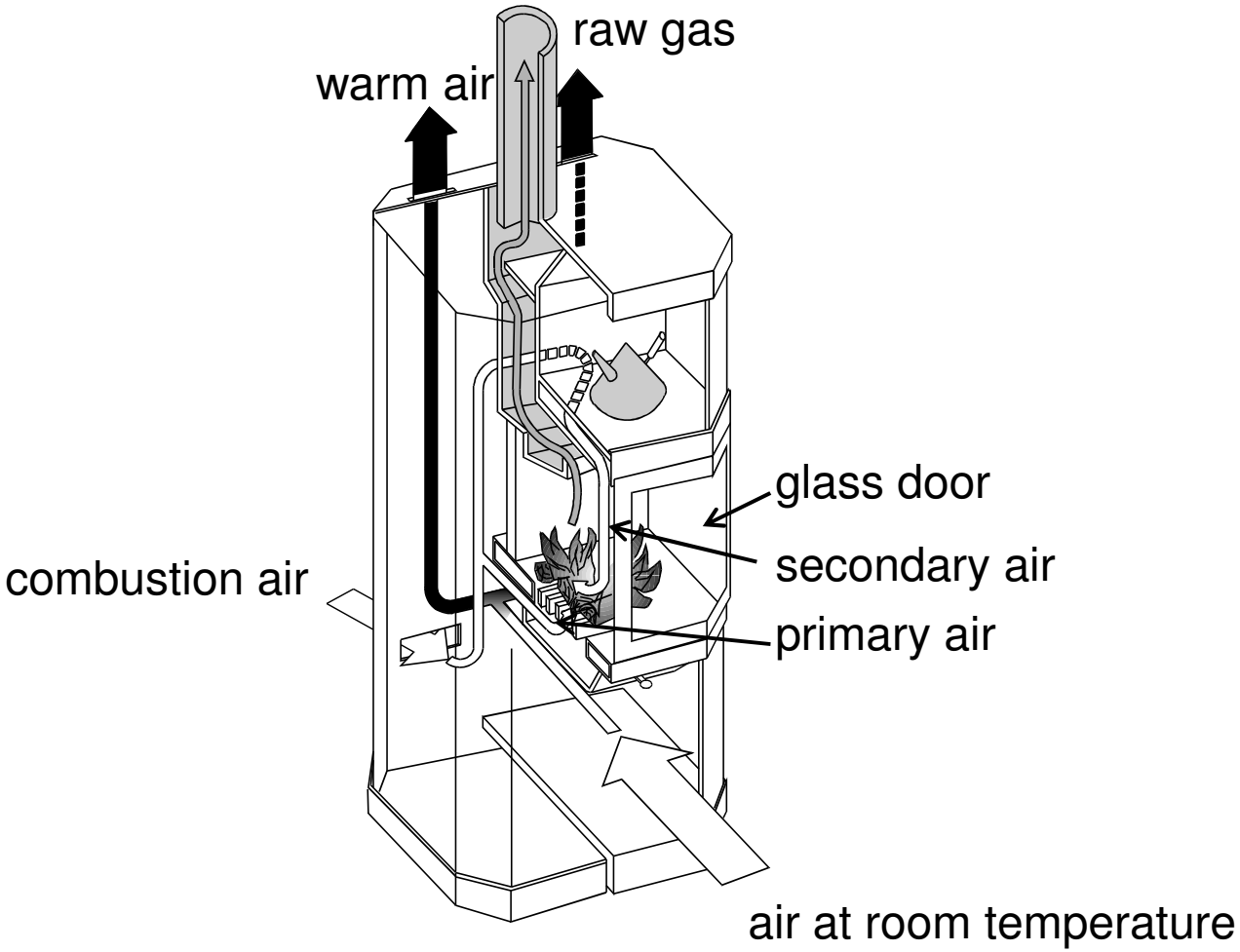
Chimney stove



Source: Kaltschmitt/Hartmann/Hofbauer 2009

General experience and recommendations:
- Chimney stoves

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Ignition of a chimney stove

- Recommended stove adjustment (e.g. air inlet, chimney flaps)
    - air inlet should be fully open for ignition procedure
    - read stove manual
- Type of ignition wood (kindling) recommended
    - fir wood
    - soft wood
- Shape and size of ignition wood recommended
    - smaller than wood for heating,
    - thin slices
    - e.g. 3 cm x 3 cm with 20 cm in length
    - 4 cm thick
    - 5 cm in diameter
- Amount of ignition wood used
    - 0.5 kg
    - 0.5 kg wood shavings and 1 kg of wood logs (3 logs)

General experience and recommendations:
- Chimney stoves

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Ignition of a chimney stove

- Preparation and assembling of ignition wood in the stove
    - small wood sticks crosswise in combustion chamber, ignition from top
    - ignition from top
    - ignition from bottom
    - wood briquettes should be cut before ignition
    - keep distance to walls
    - see additional pictures for assembling
- Type and amount of ignition aid used (e.g. paper, wax fibre bricks, mineral oil cubes)
    - no paper or carton allowed
    - no liquids
    - paper with soft wood shavings
- Time waited before 1st re-feeding of firewood
    - not specified

General experience and recommendations:
- Chimney stoves

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Ignition of a chimney stove

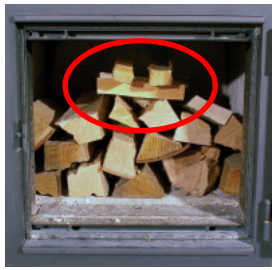
- Photographs on recommended ignition procedure
  - ignition procedure for updraft chimney stove

4 firwood pieces with 3x3x20cm with wax containing wood wool

placing wood sticks crosswise and place ignition agent below

place ingition module on top of wood logs

  - ignition procedure also depends on shape of combustion chamber!



Source: Richtig Anfeuern oberer Abbrand

General experience and recommendations:
- Chimney stoves

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Ignition of a chimney stove

-Photographs on recommended ignition procedure

- ignition procedure for chimney stove

place 2 thin sticks at the bottom

add 3 thicker wood logs crosswise

continue pilling up and add ignition aid below

ignite and close door

Source: Rika Eco plus

General experience and recommendations:
- Chimney stoves

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Operation of a chimney stove

- Recommended fuel types (species and origin, type of residues if applicable)
  - all kind of untreated wood
  - wood should be stored for at least one day at room temperature
  - only wooden fuels if stove has no grate

– Suitability for briquettes (and which types?)
  - if suitable then according to DIN 51731 HP 2 (length between 15-30 cm and 6-10 cm in diameter/height)
  - pure bark briquettes not excluded if allowed
  - wood briquettes sometimes increase their volume during combustion
  - paper and pure bark briquettes not allowed

- Recommendations of wood log size and shape (with respect to furnace size/power)
  - circumference of 20 cm recommended
  - ideal length is 5 cm shorter than length or width of fire box

- Fuel moisture limitations (min/max) (please indicate if moisture is given as wet or dry basis!)
  - usually 20 % moisture content on wet basis as maximum
  - no minimum defined
  - should not be technically dryed; can be checked by chimney sweeper

General experience and recommendations:
- Chimney stoves

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Operation of a chimney stove

- Recommended air and chimney flap adjustments
    - primary air should not be fully closed during combustion
    - after ignition air reduction
    - no air reduction during devolatilasation
    - air addition so that flames are visible

– Recommended fuel loading (in mass/volume/log number per charging, with respect to furnace size, or give examples)
    - 1 kg/100 kg of fireplace
    - only one layer of wood logs should be added
    - only single wood logs
    - either single wood logs or wood briquettes
    - never fill up whole combustion chamber with wood logs
    - fill firebox halfway to the top
    - at least one third of the height of the firebox should be left free
    - 2-3 wood logs per charging

General experience and recommendations:
- Chimney stoves

Operation of a chimney stove

- Recommendations concerning the moment or frequency of recharging
    - charcoal bed should be 10 cm high
    - when flames have died down
    - before charcoal bed does not cover grate completely (T drop)
- Recommendations concerning the mode of recharging (e.g. position/orientation/distance of log)
    - open chimney stove door slowly
    - place logs preferably with the bark side down
    - keep some space between wood logs → boards not suitable
- Recommendation for ignitability sustaining mode (partial load operation?)
    - not available
- Ash handling recommendation (e.g. full or partial ash removal before reuse?)
    - full ash removal before use and waste disposal
    - partial ash removal if charcoal bed is wanted
- Recommended flap positions when stove is cold (shut-off mode/heat loss prevention)
    - shut-off mode in general
    - close flap when charcoal is gone

General experience and recommendations:
- Chimney stoves

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Maintenance of a chimney stove

- Which maintenance actions are recommended to be carried out by the operator? (only emission or efficiency relevant issues)
  - annual maintenance
  - check for broken door sealing
  - if smoke is released into the room → open window and shut down the stove

General experience and recommendations:
- Slow heat releasing stoves

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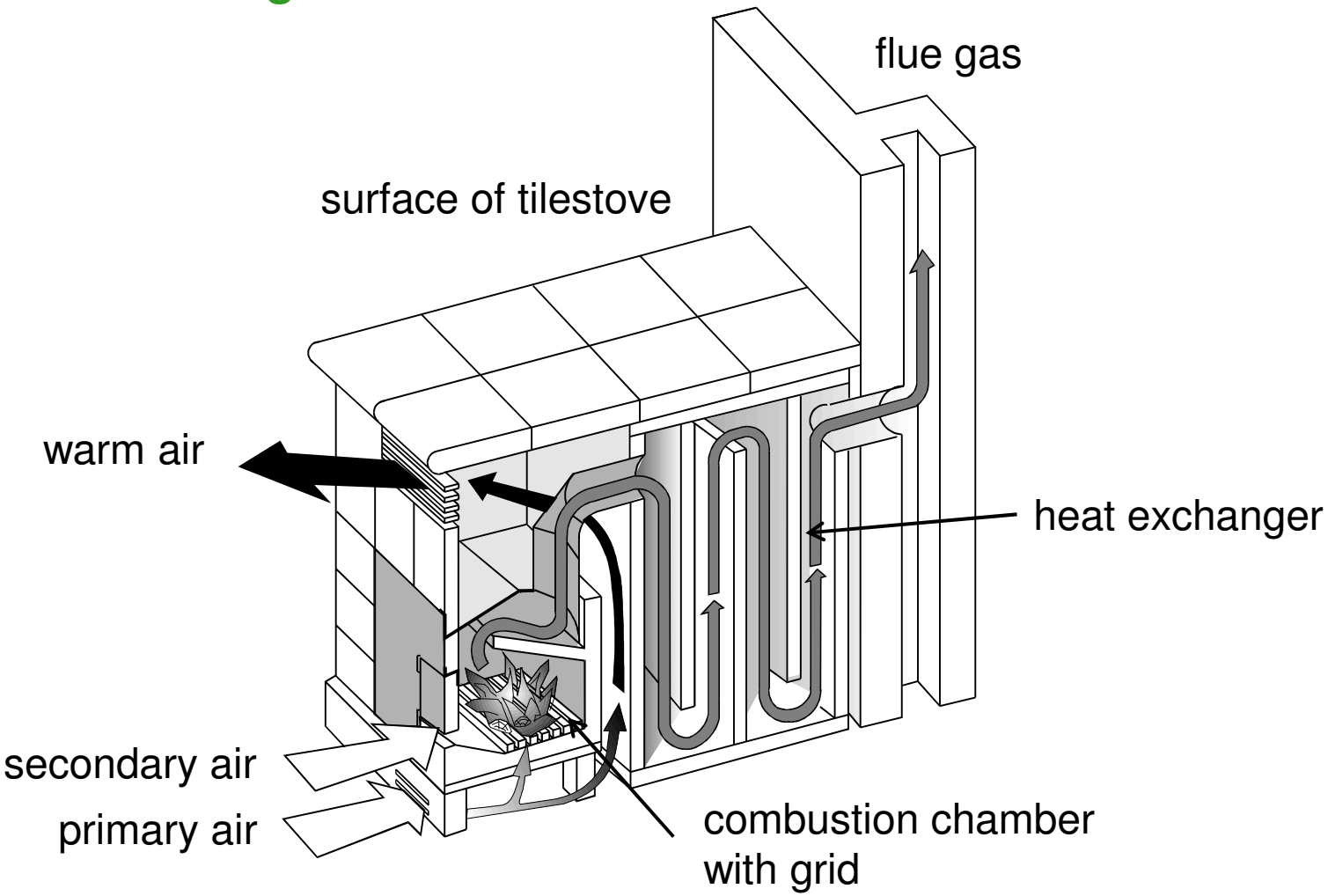
Slow heat releasing stove



Source: Kaltschmitt/Hartmann/Hofbauer 2009

General experience and recommendations:
- Slow heat releasing stoves

Ignition of a slow heat releasing stove

- Recommended stove adjustment (e.g. air inlet, chimney flaps)
    - all flaps fully open
    - for start up open flap for short cut (if available) to heat up the chimney for a better draft
- Type of ignition wood (kindling) recommended
    - not specified
- Shape and size of ignition wood recommended
    - not specified
- Amount of ignition wood used
    - 0.5 kg
- Preparation and assembling of ignition wood in the stove
    - small wood sticks and on top larger wood logs cross wise

General experience and recommendations:
- Slow heat releasing stoves

Ignition of a slow heat releasing stove

- Type and amount of ignition aid used (e.g. paper, wax fibre bricks, mineral oil cubes)
    - paper, carton, small wood sticks
    - wood shavings
- Time waited before 1st re-feeding of firewood
    - not specified
- Add photographs or drawings on recommended ignition procedure, if available
    - not available for slow heat releasing stoves
- Add other relevant information
    - none

General experience and recommendations:
- Slow heat releasing stoves

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Operation of a slow heat releasing stove

- Recommended fuel types (species and origin, type of residues if applicable)
    - all kind of wood, spruce and pine wood preferred due to longer flames
- Suitability for briquettes (and which types?)
    - yes, but less should be loaded compared to wood logs
    - never place briquettes to close to each other (expansion)
- Recommendations of wood log size and shape (with respect to furnace size/power)
    - diameter smaller than 10 cm
    - 5-10 cm shorter than furnace
- Fuel moisture limitations (min/max) (please indicate if moisture is given as wet or dry basis!)
    - below 20 % on wet basis
- Recommended air and chimney flap adjustments
    - air and chimney flaps fully open as long as flames are present
    - after flames vanished all flaps should be closed to avoid heat loss

General experience and recommendations:
- Slow heat releasing stoves

Operation of a slow heat releasing stove

- Recommended fuel loading (in mass/volume/log number per charging, with respect to furnace size, or give examples)
    - 1 kg per kW installed
    - not up to the top of the furnace
    - at least 50 % of the maximum load
- Recommendations concerning the moment or frequency of recharging
    - recharging twice a day for 24 h heat output
- Recommendations concerning the mode of recharging (e.g. position/orientation/distance of log)
    - not specified
- Recommendation for ignitability sustaining mode (partial load operation?)
    - not specified
- Ash handling recommendation (e.g. full or partial ash removal before reuse?)
    - no ash removal (only about twice a year)
    - only ash removal when ash bed is higher than 5 cm
- Recommended flap positions when stove is cold (shut-off mode/heat loss prevention)
    - all flaps should be closed

General experience and recommendations:
- Slow heat releasing stoves

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Maintenance of a slow heat releasing stove

- Which maintenance actions are recommended to be carried out by the operator? (only emission or efficiency relevant issues)
    - cleaning of hot gas tract every 2-3 years to remove depositions

General experience and recommendations:
- Stoves in general

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Features or component parts to increase performance

- Thermometers for exhaust temperatures (are they recommended?)
    - rarely recommended but used in simple automatic air control systems
- Filling level indications in furnaces (do they exist?)
    - available for pellet stoves
- Electronic status information (recharging signals?)
    - yes, when automatic air control system is integrated

General experience and recommendations:
- Stoves in general

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Features or component parts to increase performance

- Automatic (retrofit) air control systems (type, description, price, features)
    - all equipped with display and air regulation flap

Supplier	Principle	Application/Features	Price (€)
BBT Thermotechnik GmbH, Buderus Deutschland	regulation according to flue gas temperature and flow in flue gas pipe	only for own products, also for additional features e.g. room air ventilation can be included	2000
Brula GmbH	regulation according to flue gas temperature	only for own wood stoves	1000
Kutzner + Weber GmbH	regulation according to flue gas temperature and flow in flue gas pipe	suitable for all products, extended version including room air ventilation available	1800
LEDA Werk GmbH & Co.KG Boekhoff & Co	regulation according to flue gas temperature	only for own wood stoves	1400
Olsberg Hermann Everken GmbH	regulation according to flue gas temperature	only for own wood stoves	1150
Schmid Feuerungs-technik GmbH & Co. KG	regulation according to flue gas temperature and flow in flue gas pipe	only for own wood stoves, extended version including deactivation of exhaust hood available, not only stove regulation	1500
Ulrich Brunner GmbH	regulation according to flue gas temperature	only for own wood stoves, extended version including deactivation of exhaust hood available, not only stove regulation	900
WGS -Wärmegerätebau Steyr GmbH	regulation according to flue gas temperature	only for own wood stoves, extended version including deactivation of exhaust hood available, not only stove regulation	1600

General experience and recommendations:
- Stoves in general

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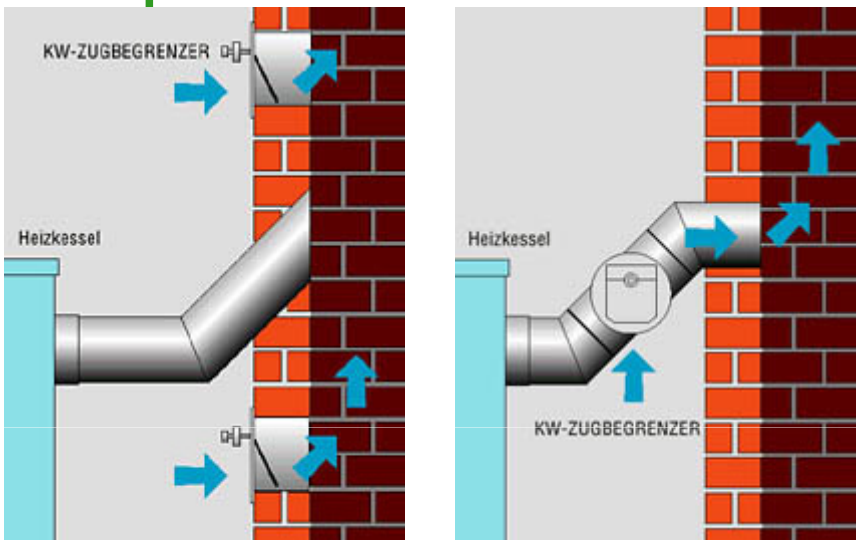
Features or component parts to increase performance

- *Bleed air flap:*
  to avoid excessive draught
  in critical stages of batch combustion



- *Temperature display for stoves:*
  to teach the user to avoid fuel charging
  which leads to too high temperatures

Research findings: **Chimney stoves**
- Effects of too high moisture content

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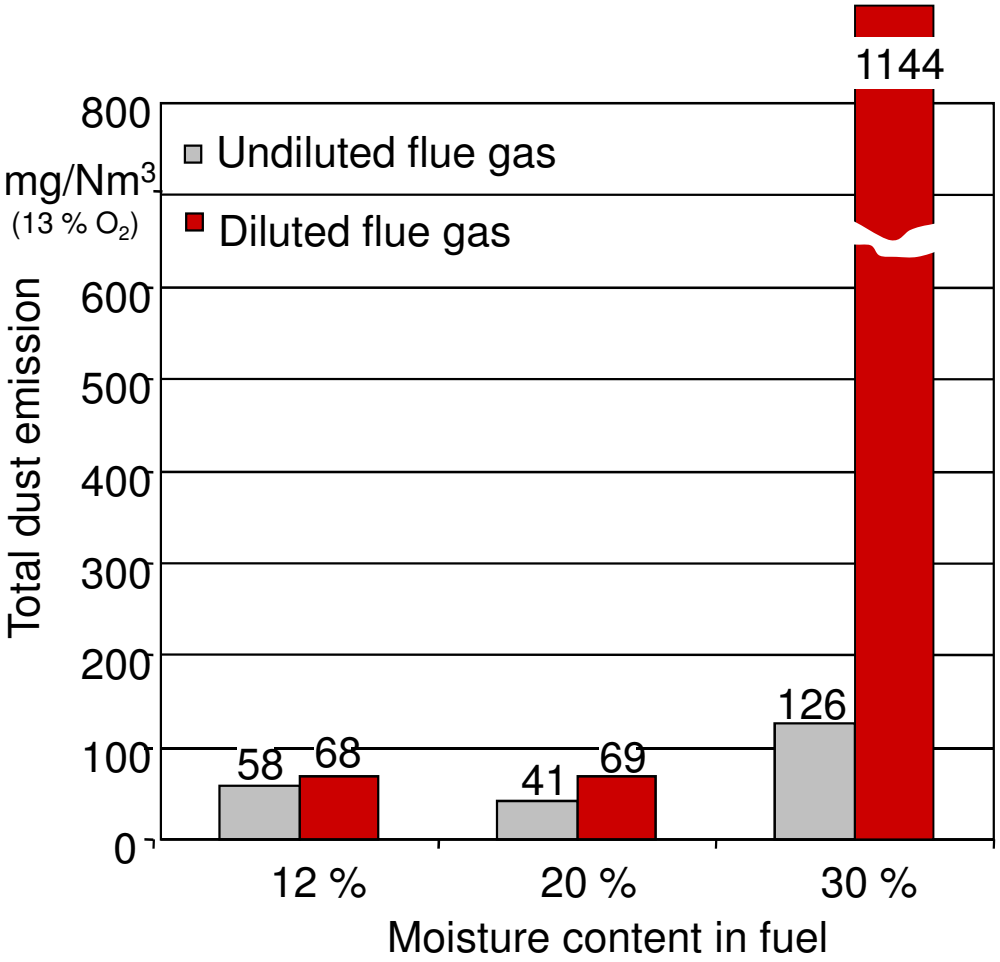

Test conditions
Stove: Wodtke Moon 7 kW (updraft)
Fuel: beech logs (25 cm)
Moisture: variabel

Chimney stove Wodtke "Moon" (7 kW, updraft)

Source: Ellner-Schuberth et. al (2010)

Research findings: **Chimney stoves - Effects of too low moisture content**

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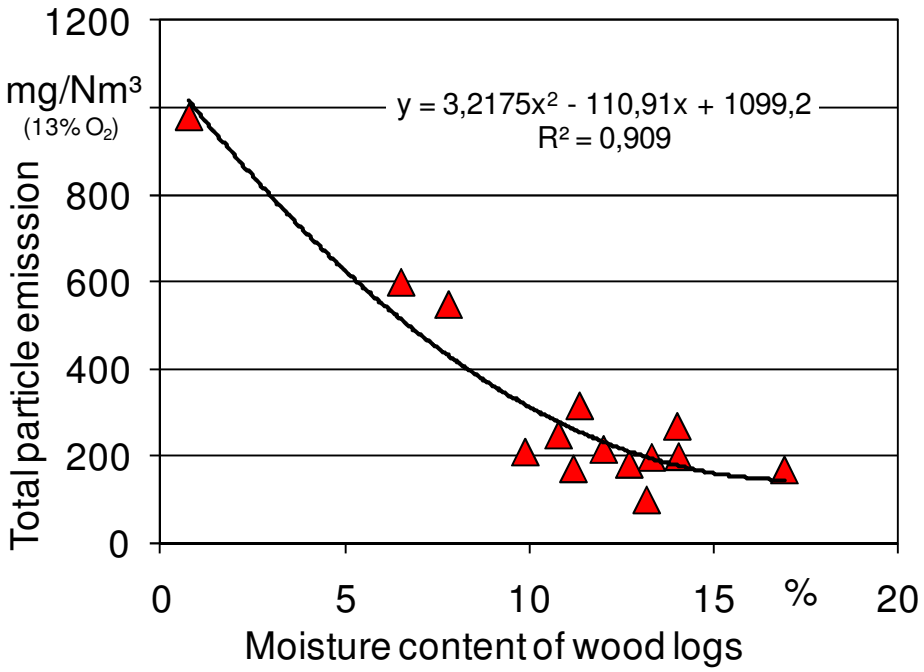
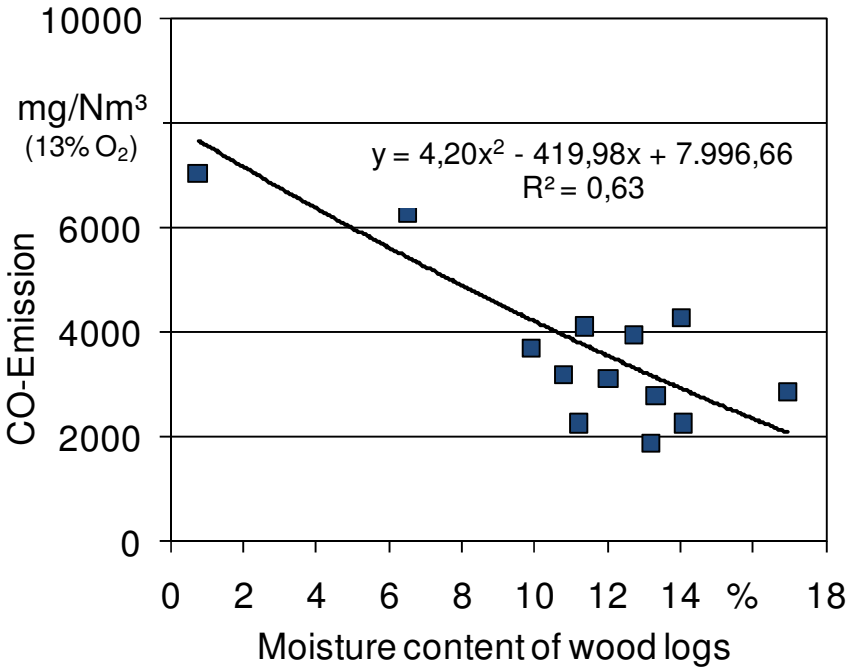
Particle emissions



Test conditions:
Log wood stove: Oregon 7 kW (updraft)
Fuel: beech logs (33 cm)
Moisture: variabel

CO emissions



Source: Kiener, S., et al. (2010)

Research findings: **Chimney stoves**
- Log size influence on dust emission

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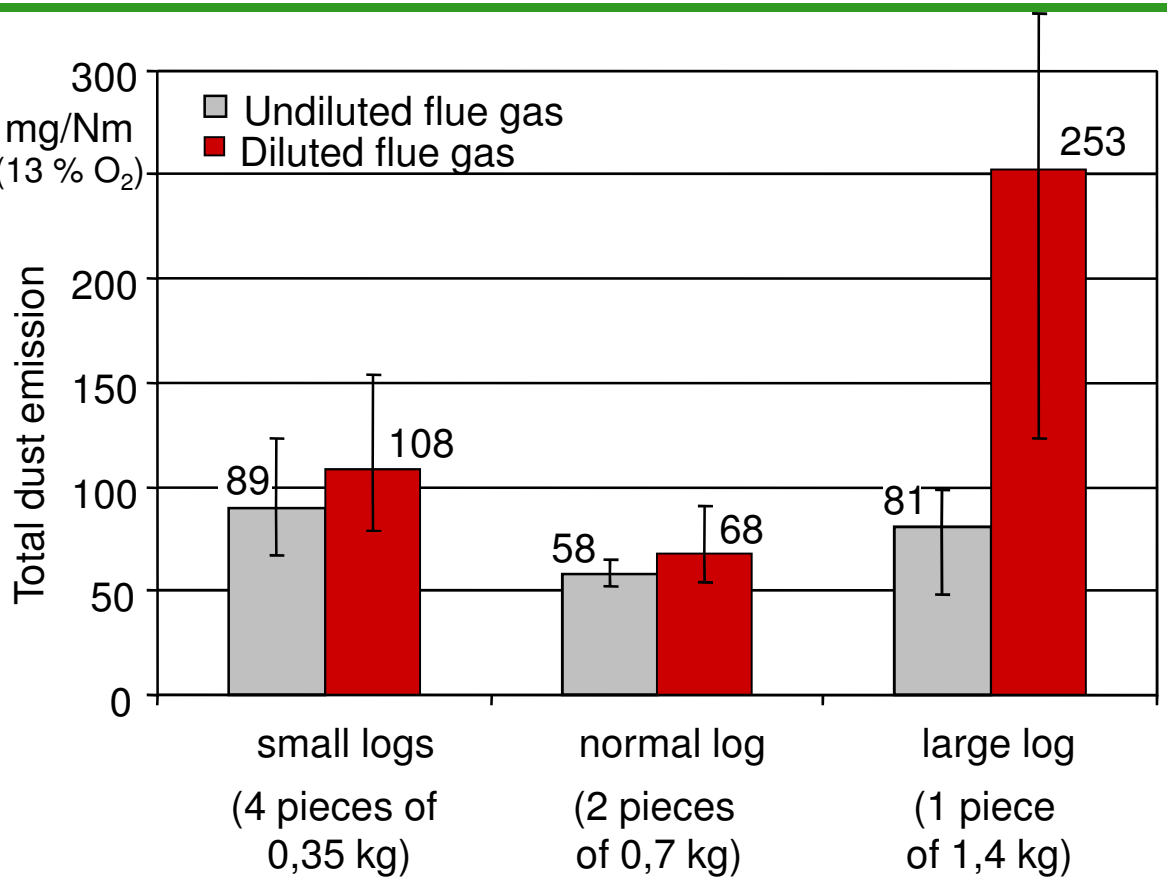

Chimney stove Wodtke "Moon" (7 kW, updraft)

Source: Ellner-Schuberth et. al (2010)

Research findings: **Slow heat releasing stoves - Effect fuel type on total dust emissions**

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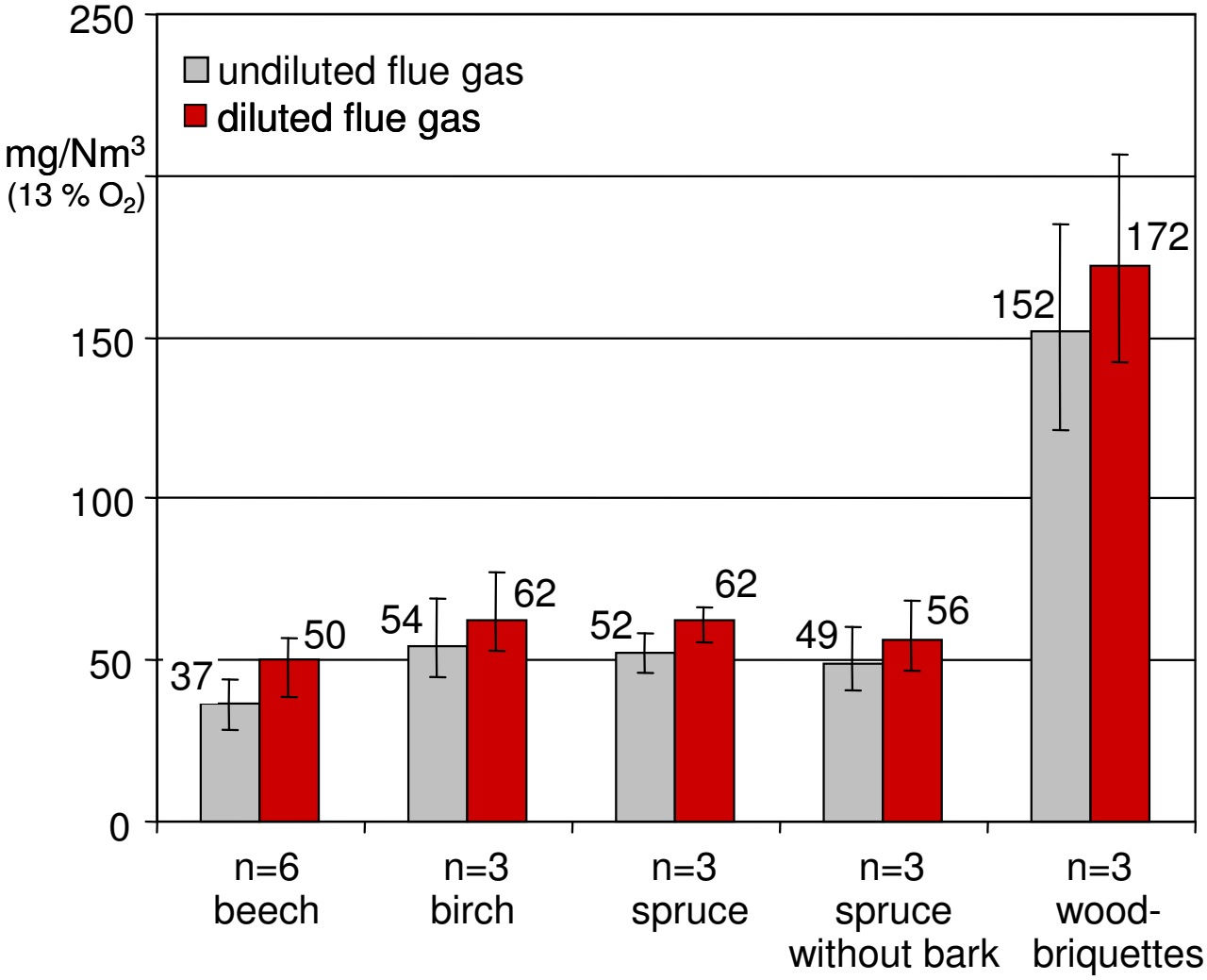

Tiled stove Brunner HKD 5.1 (10 kW)

Source: Ellner-Schuberth et. al (2010)

Research findings: **Slow heat releasing stoves - Influence of fuel load on dust emission**

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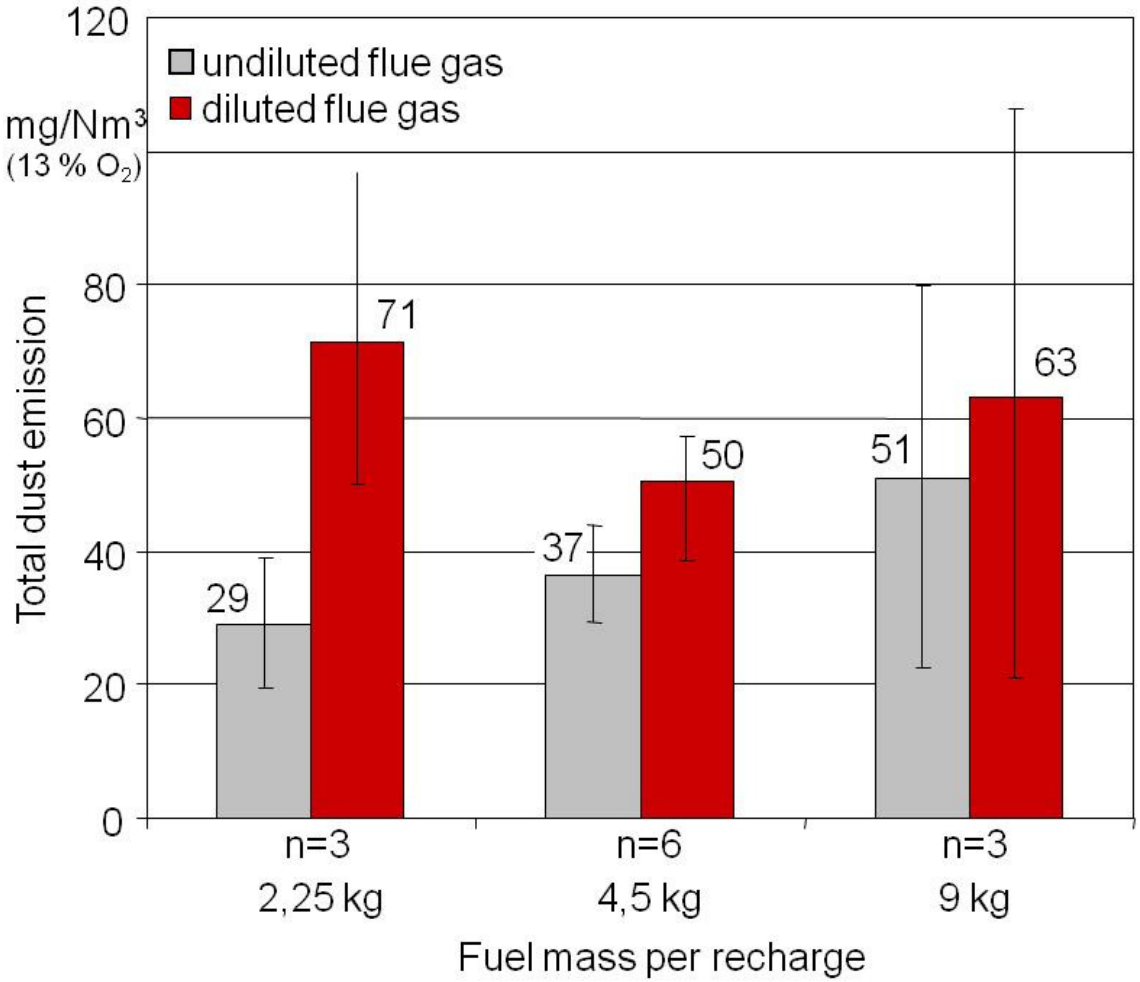

Tiled stove Brunner HKD 5.1 (10 kW)

Source: Ellner-Schuberth et. al (2010)

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